Ph. D. Dissertation in Economics

Adaptation Strategy and Selection Mechanism under Shakeout

- The Cases of Automobile and Mobile Phone Industries -

August 2014

Graduate School of Seoul National University

Technology Management, Economics, and Policy Program

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이 논문을 경제학박사학위 논문으로 제출함
2014 년 8 월

서울대학교 대학원

협동과정 기술경영경제정책 전공

길태준

길태준의 경제학박사학위 논문을 인준함
2014 년 8 월

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Abstract

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After an industry emerge and is introduced on the market, a number of firms continue to enter the industry until the net entry of firms become saturated on the point so called "Shakeout". Shakeout describes phenomenon that net entry of firms on certain industry rapidly falls although market size continue to rise.

According to the industry life cycle theory, the industry face dramatic change during shakeout period. For instance, almost perfectly competitive market would becomes monopoly or oligopoly structure during this time.

A number of economist studying empirical industrial organization have been trying to analyze survival mechanism on the period in which each firm face radical change in competitive environment. Their findings pointed out that the firm size, the time of market entrance and ex ante experience of firms before entering the new industry are significant variables to determine firm survival during shakeout process. These results do not contribute firm's strategic decision making because the factors they represented are only within environmental factors which individual firms never change. However, according to the theory regarding firm behavior in evolutionary economy, firm survival are influenced by environmental factors as well as active decision making which are called "selection" and "adaptation" in evolutionary economy context. Evolutionary economy regard firm active decision maker every moment. Therefore the aim of this research is to examine both deterministic and non-deterministic factors affecting firm survival during shakeout in one unified framework based on principle of evolutionary economy. In addition, dividing pre-Shakeout, Shakeout and post-Shakeout period to consider industry dynamics.

To measure companies' adaptation strategies objectively, this paper uses products level data distinctively. I analyzed data on 21,337 kinds of new automobile products in American automobile industry from 1905 to 1942 and 5,508 kinds of new mobile phone products from 1994 to 2012. This paper includes four companies' adaptation strategies such as technology level, technology growth, product dispersion and product difference using these data.

Main results are followings. First, companies which has higher technology growth shows higher survival rate in pre-shakeout period. Since products does not meet the consumers needs in this period. Second, higher product difference shows higher survival rate. Although dominant design was emerged before shakeout period, imitating dominant design strategy can reduce companies' survival rate. This is because companies which imitate dominant design can also surfer price competition pressure.

The implications of this research are summarized as follows. First, the research demonstrates that the principle and framework suggested by evolutionary economists are effective and valuable in explaining firm survival mechanism. It implies further that the firms are not a passive actor in survival process but an active decision maker which enable firms to overcome huddles during shakeout. Second, the result shows that using product level data is helpful to describe and understand firm behavior. Especially, it prove that firm heterogeneity can be explained by observing all products a firm makes.

Keywords: Shakeout, Industry Lifecycle Theory, Product Analysis, Evolutionary Economics, Selection and Adaptation, Survival Analysis

Student Number: 2006-21090

Contents

List of Tables

List of Figures

Chapter 1. Introduction

1.1 Study background and purpose

The economy is made up of various industries with different characteristics from one another. Some industries experience fast growth, while others decline. During such economic fluctuations, leading industries in the economy have been in a cycle of introduction and decline in the course of natural business cycles (Schumpeter, 1939). While all industries experience fluctuations, it was discovered that most industries experience similar cyclic patterns (Abernathy & Utterback, 1978; Gort & Klepper, 1982). This pattern was theorized as the industry life-cycle, and this theory has been developed based on evolutionary economics and Schumpeter's innovation theory (Gort & Klepper, 1982; Jovanovic & MacDonald, 1994; Utterback & Suarez, 1993).

According to the industry life cycle theory, once an industry has been created, a number of firms will enter into that industry. However, despite the ongoing growth of the market, the number of entering firms will decrease rapidly after a certain point of time, which is called the “shakeout phenomenon” (Klepper & Miller, 1995). The shakeout phenomenon is now considered a general event that occurs in most industries (Filson, 2001; Gort & Klepper, 1982; Klepper &

Graddy, 1990), which can also be applied to newly created industries in the future.

Around the time of a shakeout, an industrial structure change occurs, and in some extreme cases, a perfectly competitive market might be restructured into a monopoly market (Gort & Klepper, 1982). Therefore, it would be valuable to study a shakeout, since it can shed light on the causes of sudden changes in an industry's structures. From the viewpoint of firms, it can also have important implications for the identification of survival strategies at this period, when a large number of firms exit from the industry. Moreover, a study on the shakeout phenomenon is worthwhile, because most firms that survive the shakeout period are likely to remain viable in the maturity stage for a long time, and maintain their dominant position in the market.

Because of the importance of analysis on the shakeout, a large number of previous studies have attempted to identify the rules governing survival at the shakeout period (Agarwal & Audretsch, 2001; Klepper & Simons, 2000; S. Wagner & Cockburn, 2010). Most previous studies have dealt with a shakeout with respect to firm size, the time of entry of a firm into the market, and the analysis of the effects of experiences prior to entry into an industry on firm survival. However, most factors identified via previous studies did not provide any implications for firms, because those factors are difficult to control. That is, firms were regarded as passive entities that had no option but to allow for the conditions of their chosen market's environment.

On the other hand, according to the selection and adaptation concept in evolutionary economics, firms are active entities that can adapt to market environments through the adaptation process. Therefore, this study aims to provide a strategic implication that firms can apply, and that is based on the perspective of evolutionary economics, by not only considering firms' adaptation strategies, but also the selective mechanisms of the market.

1.2 Research scope and method

The most important task in the identification of adaptation strategies and selective mechanisms during a shakeout is to determine how to observe adaptation strategies. However, such determination is not an easy task, due to there being many hurdles to overcome. For example, a long history of data is required for this task, because the evolutionary process can continue for decades. In addition, since most firms get kicked out of the market during the evolutionary process of industries, these firm's financial data may not be available, let alone their methods. Above all, it is a barrier to the identification of adaptation strategies that few methods are available that allow the observation of adaptation strategies through objective data. A study by Gort and Klepper (1982) also mentioned such difficulties. They circumvented this difficulty to explain the phenomenon, although they failed to prove their theory empirically.

To overcome such limitations, this paper aimed to identify the adaptation strategies of firms through information about their previous products in the market place. A firm maintains contact with its market through its products, and competes with other firms in the sense that a consumer’s purchase behavior is triggered by their products. It is also true that we should not attempt to identify adaptation strategies through only a single product of a firm, because a firm is unlikely to fail completely in an industry due to the failure of a single product. However, if we take all the products of a firm into account, it can give insights into some trends in their overall performance. Therefore, it is expected that the adaptation strategies taken by a firm in the past can be identified through all the products they release into the market to determine the effect of their adaptation strategies on their survival.

For specificity, the performance data of products was indexed through the Hedonic price model, while adaptation strategies at a firm level such as technology levels, technology increase rates, product dispersion, and differentiation were identified by employing various techniques used in product dynamics, engineering, and business administration.

Furthermore, survival analysis was conducted at the same time in consideration of the adaptation strategies that were identified through product data, and selective factors such as firm size, entry timing of a firm into a market, and experiences prior to entry identified through previous studies. For survival analysis, Cox proportional hazards models such as time variables were used, and empirical analysis of different industries was conducted by utilizing data from the automobile industry in the early 20th century and from the mobile industry in the early 21st century. This study aimed to verify the adaptation strategies commonly taken in different environments, and how such adaptation strategies were implemented differently by industries at different stages in their respective industry life cycles. This will be examined through empirical analysis with regard to two industries, which were different in terms of their cycle stage and industry characteristics.

This paper is related to a study on industry dynamics, which was conducted within a theoretical framework of the adaptation and selection of evolutionary economics, while the adaptation strategy was focused on technical characteristics. Therefore, business strategies such as mergers and acquisitions, marketing, or capital raising strategies were not discussed in this paper. Instead, this study has focused on firm’s innovation strategies. Finally, note that since the shakeout phenomenon has been defined according to the industry life cycle theory, the chasm phenomenon, which is mainly discussed in business administration, is beyond the scope of this paper.

1.3 Contribution of this study

This paper is differentiated from previous studies in many ways; first, this study contributed to presenting and applying a study framework of selection and adaptation in evolutionary economics at the shakeout period for the first time. In addition, this study contributed to empirical analysis in consideration of the selection and adaptation concept in evolutionary economics with balance. Most previous studies did not consider adaptation strategies or only considered fragmented adaptation strategies such as innovation. However, this study overcame such limitations by considering innovation strategies from multifaceted dimensions. By considering adaptation strategies from multifaceted dimensions, firms that were viewed as passive entities can be recognized as active entities that survive through adaptation. Through such attempts, this study has contributed to the identification of adaptation strategies that can have a positive effect on survival during the shakeout, and provide an implication that can be employed practically.

From a methodological viewpoint, this study has contributed to providing a method that can identify objective adaptation strategies. That is, adaptation strategies at the firm level can be identified using product-level data, thereby enabling the consideration of the heterogeneity of firms.

This study also contributes to the explanation of the evolutionary processes of industries through product analysis, which has already been done in business administration, engineering, and product dynamics. Therefore, this study has a significant contribution as an inter-disciplinary study that connects business administration, engineering, and economics.

1.4 Paper organization

This paper is organized into six chapters as follows: In Chapter 2, the concept of the selection and adaptation of evolutionary economics is explained as a background of this study, as is the industry life cycle theory. While discussing the industry life cycle theory, which changes in the evolutionary process of industries occur was also discussed. In addition, this chapter focuses on the shakeout phenomenon in the industry life cycle, thereby explaining the efforts of the theoretical approach towards the definition and cause of occurrences of the shakeout phenomenon. In Chapter 3, the formalized facts of the selective mechanism are derived through previous studies related to firm survival at the time of shakeout, and the limitations and improvements of previous studies are explained. In Chapter 4, empirical analysis of the US automobile industry is conducted, while empirical analysis on the mobile industry is conducted in Chapter 5. Through these two empirical studies, the adaptation strategies and selective mechanisms of the industries are discovered. Finally, Chapter 6 presents the conclusion in which a summary, implications, contributions, and limitations are described.

Chapter 2. Theoretical background

2.1 Evolutionary economics and industry life cycle theory

The economy is composed of different industries working with one another. Some industries are growing rapidly, while other industries decline. During such economic fluctuations, the leading industries in an economy have been in a cycle of introduction and decline in the course of their Business Cycles (Schumpeter, 1939). Efforts to understand how industries are formed and change began over a century ago (Marshall & Marshall, 1879).

However, studies conducted due to interest in the evolutionary process of industries did not start in earnest until the 1980s (Dosi, 1982; Gort & Klepper, 1982). Previous studies were conducted based on the neoclassical model of economics, and did not focus on the process of industrial evolution in which the number of firms increased rapidly at the early stages of an industry's evolution followed by its rapid decrease in the number of firms after a shakeout, but focused on the equilibrium after industry maturation. They also modelled the steady-state of the industry through the equilibrium model or optimization of social welfare (Baumol, 1982; Douglas & Miller, 1974). Therefore, previous studies were only interested in the changes in the industry structures revealed through the phenomenon in the early stages of industry, but lacked the interest in industry dynamics, which is the process of changes.

However, scholars affected by the advancement of evolutionary economics were interested in the evolution of the industry since 1980, thereby discovering a similar cyclic pattern in most industries (Abernathy & Utterback, 1978; Gort & Klepper, 1982). This pattern is theorized, and is the result of the industry life cycle theory. Therefore, the industry life cycle theory was founded on evolutionary economics and Schumpeter's innovation theory (Gort & Klepper, 1982; Jovanovic & MacDonald, 1994; Utterback & Suarez, 1993), and this study is also based on the same theories.

A shakeout, which is the focus of this paper, is a phenomenon that occurs in the middle of the above industry development. To have an in-depth understanding of the shakeout phenomenon, it is necessary to understand the changes in industries from their generation to maturation industry first. Therefore, this paper is organized as follows:

In Section 2.2, the selection and adaptation concepts of evolutionary economics are explained as a background to the theory of analysis to shed light on the survival mechanisms during a shakeout, which is the purpose of this study. In Section 2.3, the evolutionary process of industries is discussed, based on the industry life cycle theory and changes in the industry from various dimensions. In Section 2.4, the definition, status, and causes of the shakeout phenomenon are described in detail. Finally, in Section 5, conclusions of the direction to analysis are presented based on the above background.

2.2 Selection and adaptation mechanism of evolutionary economics

In biology, organisms are selected by their natural environment and can adapt to the environment via genetic mutation. Since such natural environments continually change over time, the mechanism of natural selection also continually changes accordingly. However, even in such changing natural selection mechanisms, core characteristics do not change. One of these core characteristics is the principle of the survival of the fittest, which is the idea that species will adapt and change, and the best-suited mutations will become dominant (Williams, 2008).

Such natural selection and adaptation is a mainstream, key theory in evolutionary biology, and the selection and adaptation concept in evolutionary economics that has been derived from it can be applied to the survival of firms (Baldwin & Rafiquzzaman, 1995; Meeus & Oerlemans, 2000). Note that in evolutionary economics, selection is not done by natural selection, but by market mechanisms, while adaptation is done via the efforts of firms rather than through gene mutation, in contrast with evolutionary biology, which is the main difference from evolutionary biology. Adaptation in evolutionary biology is expressed through coincidental gene mutation, which means that organisms cannot modify themselves intentionally, whereas adaptation in evolutionary economics can be intentionally made by firms (Nelson & Winter, 1982).

This has left a lot of possibility for firms to adapt themselves as they might wish. If they adapt well to changes in the market environment, they can survive within selection mechanisms in the market. Even if a given condition is disadvantageous for them, they can always find a way to survive through adaptation efforts. Therefore, two aspects shall be considered simultaneously to understand firms' survival. The first is the selection mechanism in the market, and the second is the adaptation strategy of firms that satisfies the selection mechanisms.

These two factors do not work separately, so should be considered simultaneously. As explained in evolutionary biology, as an environment changes over time, the mechanisms of selection and adaptation can also change, so dynamic characteristics shall be considered.

Therefore, the next section will discuss how the market environment can change according to the evolutionary process of industry as a background for the selection mechanism.

2.3 Evolution of industry and the industry life cycle theory

The industry life cycle theory is a representative theory that explains the evolutionary processes of industry, which theorizes that the development of industry has a cyclic pattern (Abernathy & Utterback, 1978; Gort & Klepper, 1982). Such a cyclic pattern is quite dynamic, in that it showed more difference within the same industry over time than the differences revealed between industries (Geroski, 1995). Furthermore, such a phenomenon does not only occur in a specific industry, but is common to most industries (Filson, 2001; Gort & Klepper, 1982; Klepper & Graddy, 1990). This dynamic change can be seen in many aspects of industries, such as innovation, production volume, firm sizes, regimes, and entry and exit rates.

The next sections will discuss changes according to the evolutionary processes of industry, in terms of various perspectives.

2.3.1 Changes in terms of innovation

It can be observed that there are changes in the general terms of innovation when a new industry is introduced and allowed to mature. In general, the introduction of an industry is triggered by radical innovation, followed by gradual innovation thereafter. The radical and gradual innovations alternate as that industry's evolution continues (Abernathy, 1978; Gort & Klepper, 1982; Utterback & Abernathy, 1975) and the changes in industries are theorized as a cross between radical and gradual innovations (Anderson & Tushman, 1990; Henderson & Clark, 1990; Tushman & Anderson, 1986).

In addition, changes in terms of product and process innovations occur. In the early stages of an industry, product innovation occurs first, due to consumer requests or the advancement of science and technology (Malerba & Orsenigo, 1996). Then, the focus of innovation moves to the process of innovation as the industry matures (Gort & Klepper, 1982).

In the industry life cycle theory, the emergence of industry is recognized by the introduction of products that present technological opportunities. To have such technological opportunities, a number of firms attempt to enter by implementing a variety of product innovations. These technology opportunities arise discontinuously. Although technological discontinuity is an outcome of experience, it can also occur through a purpose-oriented innovation process (Nelson & Winter, 1977).

Since products at their early stages are generally primitive, consumers are less willing to buy them. However, competition increases as more new companies enter into the industry over time. As a result, the quality of products continually increases, while prices decrease less rapidly. This will result in the increase of products' values, followed by increases in sales (Agarwal & Bayus, 2002).

At the early stages of an industry, a single product cannot dominate (Utterback & Abernathy, 1975). At this stage, firms observe customer reactions to their products with short production processes, and introduce their products into the market by improving upon them. In the early stages of a new industry's introduction, products that retain early designs are manufactured using relatively non-specialized machinery, and sold through various experimental techniques (Williamson, 1975). Therefore, a newly introduced industry is characterized by a high innovation rate for new products in terms of R&D expenses, relative to their attempting experimental techniques (Audretsch, 1995b). It is also found that there is a higher application rate for patents in the early stages of industry than in its mature stages (Agarwal, 1998). In addition, companies compete with one another to produce dominant design products through various experimental techniques in the early stages of industry. Although their success rate is low, a few successful companies may enjoy high growth rates.

In contrast, the opportunity to set the standardization of products through innovation activities becomes more difficult at the mature stage. Although radical innovations are less dominant in this stage, companies newly entering into an industry may do so to claim a strategic niche. According to the theory of strategic niches, a firm retains a small portion of the business, but takes a niche that cannot be accessed by larger firms to generate similar levels of profit as larger firms (Caves & Porter, 1977; Newman, 1978; Porter, 1979). In the mature stage of the cycle, disadvantages due to the smaller scale experienced by small companies can be avoided through the above strategy that targets strategic niches. Therefore, the size of a company may confer the advantage of reducing the possibility of failure in the early stages of an industry's introduction, whereas this benefit is reduced at the mature stage (Newman, 1978).

Furthermore, product design at the mature stages of an industry is standardized and uniform, and products with superior technology at this stage have a premium advantage. Management and production technology at this stage reaches to a level where no room for improvements can be found

(Williamson, 1975). Therefore, the market at this stage may continue to grow, but the prediction of growth can be done due to some regularity found at this stage. The likelihood of major innovations is reduced, and improvements and refinements become the main activities at this stage. For example, the mature automobile industry has shown a relative decreasing trend of new product innovation, based on their R&D expenses (Audretsch, 1995a). Furthermore, patent acquisitions are gradually reduced at the mature stage (Agarwal, 1998).

2.3.2 Changes in terms of production volume and firm size

Production volume is generally small in the early stages of industry, as business environments at this stage have high uncertainty. Therefore, companies are mainly competing to have the dominant products in the industry during the early stages of industry introduction. Contrastively, products are standardized and made uniform with the aid of mass production during the mature stage of an industry. Companies increase their production volumes to achieve economies of scale in production (Klepper & Graddy, 1990). In addition, a continuous relationship between customers and suppliers tends to require the minimization of changes so that market share does not change rapidly (Williamson, 1975).

There are also differences between industries at their early and mature stages, in terms of the distribution of company sizes within an industry. At the early stages of industry, most companies in said industry are small, and their production methods are inefficient (Malerba & Orsenigo, 1996). On the other hand, at the mature stage of industry, companies are larger, creating economies of scale and showing a high level of industry concentration (Utterback & Suarez, 1993).

2.3.3 Changes in terms of regime

There are also many changes in industry regimes between the early and mature stages of an industry. Here, the regimes proposed by many scholars have been summarized, and changes in industry environments are identified through regimes.

Tushman and Anderson (1986) categorized discontinuity. According to them, discontinuities can be categorized as one that destroys existing capabilities, and one that improves upon existing capabilities. The destruction of existing capabilities is primarily done by newcomers, while the improvement of existing capabilities is primarily done by existing companies. Existing companies add new knowledge into their existing knowledge, create entry barriers, and increase the minimum requirements for entry.

A new industry is created by innovations that destroy existing capabilities, and the industry dynamics at this stage are called an entrepreneurial regime (Audretsch, 1991). At this stage, information plays a critical role. Nelson and Winter (1982) described two different technological regimes with fundamental differences in their knowledge conditions. An entrepreneurial regime is not favorable for the innovation activities of existing firms, but is favorable for innovative newcomers. Therefore, this stage is advantageous for innovative new firms (Winter, 1984).

In addition, an entrepreneurial regime can show similar characteristics to that of competitive regimes, as proposed by Schumpeter (1939). This stage is generally confusing, and can be described as a time to pioneer a new path. Such innovation tends to be produced by newcomers. The technological regimes are well matched with the early stages of the industry life cycle. As a result, entries at the early stages tend to be based on more innovation-oriented activities compared to at the mature stage. Entries at the early stages of industry introduction are quite often employed as a transport means to introduce innovations (Geroski, 1995).

On the other hand, as industries mature, there is a change in their regimes. A regime at the mature stage of an industry is called a routinized regime, which is the opposite concept of the regime explained above. Innovations that improve upon existing capabilities are mainly driven at this stage. This stage is more advantageous to existing firms that hold more knowledge and experience of the industry than newcomers (Gort & Klepper, 1982).

Audretsch (1995b) described and modeled the aspect of entry and exit due to regime changes figuratively as the *revolving door* and the *replacing forest*. According to the revolving door industry model, firms that are successful at continuous innovation survive, whereas firms that are temporarily successful at innovation enter, but then tend to exit quickly. Newcomer firms in the replacing forest industry try to replace existing firms; therefore, although innovation in this model only occurs once, the ramifications are significantly large.

The revolving-door model models industries that have achieved economies of scale under a routinized regime, while the replacing forest model models newly introduced industries under an entrepreneurial regime.

2.3.4 Changes in terms of entry and exit

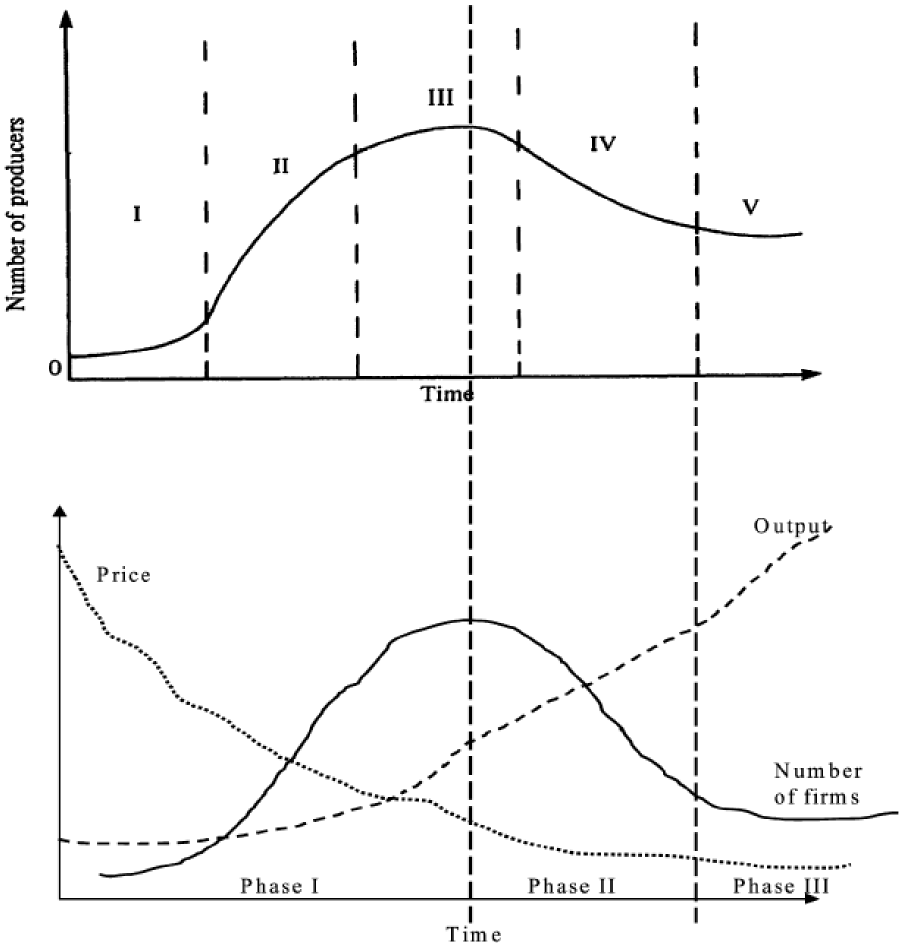
The entry and exit of industries is important to study, because it demonstrates the industry’s structural characteristics. As product sales volumes increase, the cost of entry to the industry increases. This generally peaks at the early stages of an industry’s evolution (Gort & Klepper, 1982). This stage also experiences both quality improvements and the price reduction of products.

Many scholars have categorized the industry life cycle based on characteristics such as entry and exit, or the number of total firms in the industry. The upper side of Figure 1 shows the five evolutionary stages of a new product industry that was proposed by Gort and Klepper (1982), displaying the relationship between the number of firms and time. The lower side of Figure 1 shows categorization by three stages. The five-stage categorization of the industry life cycle has been referenced widely (Agarwal & Gort, 1996; Gort & Klepper, 1982). However, recent studies have also used a three-phase division of prior to, during, and after the shakeout period (Dinlersoz & MacDonald, 2009; Utterback & Suarez, 1993). The advantage of a three-phase division is that the second stage, which starts the reference time earlier than when the number of firms reaches a peak, provides more clarification than the five-stage classification; the last stage of the three-phase division is equivalent to the last stage of the five-stage classification. This paper follows the three-phase division, because it is more focused on the shakeout period. However, it is not significantly different to the five-stage division.

The changes in entry and exit, and the number of total firms in each stage on the basis of the five-stage division are as follows: In the first stage, only a small number of firms have entered the industry, so few firms exist within that industry. In the second stage, the number of firms entering increases rapidly;

however, the increase in rate gradually decreases as it reaches the third stage, where the number of entries and exits become similar to one another, and the number of firms is relatively stabilized, albeit temporarily. In the fourth stage, the number of firms decreases rapidly despite the continuous growth of the industry due to the shakeout period. In the fifth stage, the number of firms stabilizes again, as neither entries nor exits occur. This stabilization continues for a considerable period of time. The classification of the evolutionary stages can be explained on the basis of the classification of basic changes such as technological innovation and the level of competition that occur at an industry level.

Table 1 shows the characteristics of industries according to their five-stage division, by summarizing the industry changes from various perspectives described above, including the characteristics of entries and exits that occur at each stage, while Table 2 shows the same according to the third-stage division.



Source : Dinlersoz and MacDonald (2009)

Figure 1. The stage classification of industry life cycle

Table. 1. The characteristics of each five stage according to the industry life cycle theory

	Stage 1	**Stage 2**	**Stage 3**	**Stage 4**	**Stage 5**
Entry	Very few	Increase	Normal	Very few	Very few
Exit	Few	Few	Normal	Increase	Very few
Number of Firms	Very few	Increase	Max	Decrease	Stable
Industry Concentration	Very low	Low	Low	Sudden increase	Very high
Firm Size	Mid-small	Mid-small	Larger	Large	Large
Entry Barrier	Low	Low	Normal	Increase	High
Focus of Competition	Performance	Dominant Design	Performance to Price	Price	Price
Output	Low	Sudden increase	Increase	Increase	Slow increase
Product Price	High	Sudden decrease	Decrease	Decrease	Slow decrease
Amount of Innovation	Normal	Max	Normal	Max patents	Decrease
Innovation Type	Product innovation	Product innovation	Product to process	Process innovation	Process innovation
Shakeout	X	X	X	Shakeout period	X

Table 2. The characteristics of each three stage according to the industry life cycle theory

	Pre-Shakeout Period	Shakeout Period	Post-Shakeout Period
Entry	Max	Few	Few
Exit	Few	Max	Few
Number of Firms	Increase	Sudden decrease	Stable
Industry Concentration	Low	Sudden increase	Very high
Firm Size	Mid-small	Mid-small to Large	Large
Entry Barrier	Low	Increase	High
Focus of Competition	Performance	Performance to price	Price
Output	Increase	Increase	Slow increase
Product Price	Decrease	Decrease	Slow decrease
Amount of Innovation	Normal	Max patents	Decrease
Innovation Type	Product innovation	Product to Process	Process innovation

2.4 Definition of the shakeout phenomenon and cause of occurrence

As discussed earlier, the number of firms increase as sales volume increases after a new industry emerges. However, at some point, a shakeout comes into effect, decreasing the number of firms, even as the market continues to grow. Around this time, most industrial characteristics such as the regimes of industry, innovation type, entries and exits, and industry concentration change. Therefore, a study is required to focus on the shakeout phenomenon that is centered on this change. In particular, with regard to industry structure, a perfectly competitive market can change into a monopoly market in some extreme cases (Gort & Klepper, 1982). Therefore, the causes of these changes in the industry structure can be determined if we have an in-depth understanding of the shakeout.

Furthermore, a shakeout is a critical period of life and death for corporations, since it is a time when the number of firms decreases rapidly. It is also noted that the firms that survive the shakeout may enjoy a stable, monopolistic position for a considerable time in that industry.

In terms of the requirements of innovation, the number of firms is also important socially. With respect to patents, which are one of the main parameters in the evolutionary perspective of the market, Agarwal (1997) reported that as the later stages in an industry's life cycle are approached, the patent-related activities of firms are reduced. He also reported that technologically innovative activities in most product markets are reduced as the number of firms in the industry decreases. Diversity tends to be recognized as a prerequisite condition in the creation of many innovations. Since a number of firms represent such diversity, sudden changes in the number of firms may be sufficient to draw our attention to the shakeout phenomenon. It has also been reported that the shakeout phenomenon occurs in most industries (Filson, 2001; Gort & Klepper, 1982; Klepper & Graddy, 1990). Therefore, stakeouts are expected to occur in many industries created in the future, so the in-depth understanding of stakeouts based on study achievements will be necessary in the future.

Accordingly, this section reviews the definition and current status of the shakeout phenomenon for our in-depth understanding of this phenomenon, and summarizes formal models to identify the causes of the shakeout.

2.4.1 Definition of the shakeout phenomenon

The shakeout phenomenon refers to the rapid reduction in the number of firms despite the increasing market size in an industry after a large number of entries have been made (Klepper & Miller, 1995). Although many different theories can be made with regard to the shakeout phenomenon, most researchers agree that the reduction in product dispersion and innovation-oriented changes from production innovation to process innovation could increase production volumes, but sales volume cannot increase indefinitely. Therefore, market share is restructured based on the firms that have larger capabilities, while other firms are kicked out of the market. Such massive destruction is called a shakeout (Klepper & Simons, 2005).

A shakeout is not a phenomenon that only occurs in specific industries, but a general type in the evolution of new industries, which has been observed in most industries (Filson, 2001; Gort & Klepper, 1982; Klepper & Graddy, 1990). Shakeouts are generally known to occur in an early stage of new industries according to the industry life cycle theory, but they can also occur in mature industries (Bergek, Tell, Berggren, & Watson, 2008).

However, not all industries experience a shakeout. Some researchers are of the opinion that a shakeout does not occur in an industry if continuous spin-off occurs or if generalists and specialists are able to coexist (Bonaccorsi & Giuri, 2000; Buenstorf, 2007). It is also reported that a shakeout does not occur if new niches and submarkets are created continuously (Klepper & Thompson, 2006; Swaminathan, 1998).

In contrast, technological changes induce a shakeout, so a shakeout may be generated in mature industries due to technological changes (Bergek et al., 2008). Contemporary industries tend to face shakeouts earlier than traditional industries (Agarwal & Gort, 2001; Day, Fein, & Ruppersberger, 2003).

2.4.2 Cause of occurrence of the shakeout phenomenon

A number of researchers have suggested the causes of the shakeout phenomenon through modeling to understand why the number of firms decreases rapidly despite market growth in the corresponding industry. In this section, the core theories that can explain the cause of the occurrence of the shakeout phenomenon are presented and summarized comprehensively.

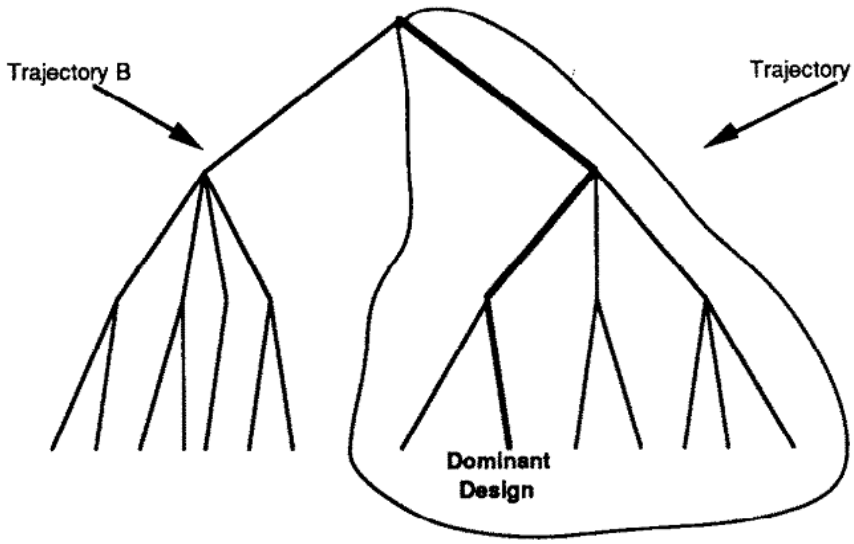
The Dominant Design Theory proposed by Utterback and Suarez (1993) is the most widely known theory; it aimed to explain the shakeout phenomenon through the introduction of dominant design. Figure 2 shows the schematic diagram of this model.

The concept of dominant strategy, introduced by Utterback and Abernathy (1975), considers that de facto standard is determined by major technological competence. Dominant design are followed by allegiance of consumers and a number of competence as well. In the wake of emergence of dominant design, source of competitiveness laid in price rather than level of technology or design

(Utterback and Suarez, 1993). Therefore, what we have to take care is that dominant design does not always means the best technological combination. For one instance, QWERTY-typed computer keyboard has been in position of dominant design for many decades despite its inferiority in view of technological competence (Diamond, 1997). Since it is difficult to practically observe and specify dominant design in every industry, some studies have been criticizing application of concept of dominant design in empirical researcher (Murmann & Frenken, 2006).

Companies that did not complete product standardization and process innovation cannot compete effectively against companies that have completed them. Since consumers demand standardized designs, firms race to produce standardized products at a low price. If a new product design dominates the market, other entries to the market are reduced, thereby creating the shakeout phenomenon.

In succession of the theories of this study, Cabral (2012) embodied the Dominant Design Theory using the concept of uncertainty and sunk cost. According to his study, firms that do not follow the path of dominant design have difficulties due to their sunk costs caused by development in different directions, even if firms are then able to follow the dominant design path later. Therefore, firms invest with small capabilities at the early stages of industry evolution. Since firms can enter into an industry with small capabilities at the low entry barrier stages, a large number of newcomers are able to enter. However, if a dominant design emerges once entries are stabilized to some extent, firms that survived with firm technology development directions for the future are then able to invest actively in a long-term optimized scale, and firms are able to increase their size at the same time. However, if the market cannot grow at the same rate as the increase in the size of firms, this causes a shakeout.



Source : Utterback and Suarez (1993)

Figure 2. The conceptual description of dominant Design

However, considerable criticisms can also be made of Dominant Design Theory. For example, the emergence of a dominant design may be a special case, and it is a just one example among many possible cases in a market (Windrum & Birchenhall, 1998). Products such as helicopters that are sold in a narrow market may reduce diversification, whereas products such as airplanes that can be sold in a wide range of markets may have various niche markets, thereby creating various dominant designs.

In addition, an empirical study that compared the introduction time of dominant designs and the influence of competition from newcomers in the early stages suggests that a shakeout was more affected by the influence of competition with newcomers in the early stages rather than the influence of the dominant design (Klepper & Simons, 2005). However, except for some studies that do not agree with the dominant design theory, most studies acknowledge that the cause of the shakeout phenomenon can be explained via the concept of dominant design theory.

A model proposed by Jovanovic and MacDonald (1994) modeled the evolution of an industry using the difference of concepts between invention and innovation, and explained shakeouts through the model. Invention evolves from other industries, while firms enter into industries to follow technological opportunities that can garner innovation from inventions.

Firms that are successful in technology application and are able to scale themselves to the optimum size by reducing unit costs will survive, while other firms will be kicked out.

Accordingly, firms that perform such innovations earlier will have advantages over firms that are successful in innovation later, thereby kicking them out. Therefore, this model derives a result that supports First Mover Advantage.

Klepper (2002b) presented that the shakeout phenomenon was not caused by events such as the advent of specific technologies or dominant design, but by the continuous process of competition. According to his theory, a shakeout occurs due to economies of scale in research and development (R&D). Larger firms have advantages with regard to R&D, whereas newcomers in the later stages realize that they have difficulty following larger firms in terms of their R&D scale. Following technological developments, the prices of products continue declining, resulting in aggravated profitability and a reduction in new entries, thereby kicking out lower performance firms, which causes the shakeout. Klepper said that this process occurs because it of the focus on product innovation at the early stages, followed by process innovation as the industry matures to some extent, and claimed that the above-mentioned phenomenon occurs frequently in the process of an innovation-oriented industry.

Other scholars such as organizational ecologists have attempted to explain shakeouts by means of the density dependence theory. At the early stages of an industry's evolution, products or systems are not recognized by consumers, but the diffusion of products begins as the number of related firms increases, then products are more often recognized socially (Carroll & Hannan, 2000). Due to the diffusion of products, new large firms enter the industry. However, as the level of competition becomes fiercer, firms are kicked out of the race more often, thereby creating a shakeout.

The above-mentioned theories explain the causes of a shakeout, largely through two routes. The first explanation of the causes of a shakeout blame excessive entries; a large number of competitors enter the industry because they expect large profits and market share as they have witnessed in the rapid growth of the industry. However, as competition becomes stronger, some of them are disappointed and kicked out of the market (Aaker & Day, 1986). Therefore, it is a natural consequence that most firms are kicked out of the race quickly, because the shakeout occurs soon after the massive increase in the rate of firms' entrance (Horvath, Schivardi, & Woywode, 2001).

The second cause of a shakeout is technological development; the proponents of this theory believe that there is no causality between excessive entry and the occurrence of a shakeout, so the high correlation between them is coincidental (Klepper & Miller, 1995). The theories of Utterback and Suarez (1993), Jovanovic and MacDonald (1994), and Klepper (2002b), which exclude the organizational ecology perspective, see the cause of a shakeout as changes in technology; the present paper subscribes to this view.

2.5 Sub-conclusion

This section discusses the changes in industrial environments from various dimensions as industries evolve. The focus of innovation moves from product innovation to process innovation, while products change from experimental products with low purchase willingness to standardized, normalized products. In contrast with the early stages of industry, in which small- and medium-sized firms are the main actors, the proportion of large-size firms increases in the mature stage of industry. Market concentration also gradually increases as the industry evolves. In terms of regimes, an industrial environment changes from an entrepreneurial regime to a routinized regime.

It was also found that the above changes occurred around the time of the shakeout phenomenon. Thus, it can be said that the shakeout phenomenon is a key part in industries' life cycles. As such, the shakeout phenomenon not only plays an important role in the industry life cycle, but is also a time of many firms' exits. As a result, the discovery of a law of survival during this period would be extremely important in terms of the life or death of involved firms. In addition, this is a period of big changes in terms of industry structure, which may also contribute to related studies.

Furthermore, the concept of adaptation and selection in evolutionary economics would be helpful as a study framework to discover the law governing the survival of firms. According to this concept, adaptation and selection are not independent concepts from one another, but have to be considered simultaneously. Therefore, while studying the survival of firms during the shakeout period, the adaptation strategy of firms and selection mechanisms of markets should be considered simultaneously. This paper aims to identify the law governing survival during the shakeout period by following the above theoretical background. First, in the next section, previous studies on the survival of firms at the time of a shakeout are summarized from this perspective, while formalized facts and the limitations of previous studies are derived accordingly.

Chapter 3. Adaptation strategies and selection mechanisms during the shakeout period

3.1 Frame of literature review

Over the last 30 years, a large number of empirical results about the survival of firms at the time of a shakeout have been accumulated. However, contradictory empirical results have been reported, due to the use of various analysis frameworks and heterogeneous data. Therefore, it is necessary to summarize the results by dividing them into results that have occurred under specific circumstances, and formalized facts that can be generalized. Therefore, this chapter aims to summarize previous studies in terms of their perspective of the selection and adaptation of evolutionary economics, which is the framework of evolutionary economics. The most distinctive characteristic of evolutionary economics is the acknowledgement and consideration of dynamics and heterogeneity over time. Therefore, previous studies can be summarized with the analysis framework used in Chapter 3 to determine whether changes and heterogeneity over time were taken into consideration.

When summarizing the study results, four major subjects, which were most often studied in the empirical analysis related to the survival of firms at the time of shakeout, were selected. That is, formalized facts that can be generalized from studies on firm size, the entry timing of firms, the experiences of firms prior to their entry, and the innovation of firms are derived from within the above-mentioned framework. In summary, this chapter verifies whether adaptation strategies and changes in industrial characteristics over time are taken into consideration, and derives formalized facts with regard to those four main areas.

3.2 Adaptation strategies and selection mechanisms under shakeout

3.2.1 Size of firms

According to the modeled theory of the industry life cycle, there is a positive correlation between the size of a firm and its survival probability. According to a model proposed by Utterback and Suarez (1993), firms that cannot achieve product standardization and process innovation through dominant design cannot win against firms that have achieved them. Large-size firms create barriers using economies of scale. As a result, excess production occurs while the prices of products decline. This is the primary reason that many firms get kicked out of the competition. Differentiated innovation in a model proposed by Jovanovic and MacDonald (1994) plays a role in increasing the optimum size of firms. Due to such effects, small- and medium-sized firms are kicked out of the market by the larger firms. Finally, according to a model by Klepper (2002b), an effect of economies of scale in terms of R&D capabilities induces the exit of firms. Since large-size firms have higher expectations on profits due to their R&D investment, they have more reasons to invest in R&D than smaller firms. Product prices continue declining due to larger firms investing in R&D, resulting in smaller firms being unable to compete with them, resulting in a greater likelihood of smaller firms exiting from the race.

In addition, Jovanovic (1982) modeled and analyzed the relationship between firm size and survival probability with a function of the theoretical efficiency level of firms, which was later extended by Pakes and Ericson (1998). In these two studies, the costs faced by newcomers are arbitrary and different, depending on firms, while newcomers do not know their own cost structure. Their own cost structure and relative efficiency can be learned via the process of gaining actual market experience. If their outcomes after entry are better than expected, their business size will expand; otherwise, their business size will shrink and they will likely be kicked out of the industry. According to the firm selection theory, the size of a firm is small at the entry timing, or small enough to produce products at an appropriate volume if required, but it may extend, depending on the firm’s outcome after entry. Some entry firms may become successful, while a firm that produces an appropriate level of volume may remain small or get kicked out of the market entirely, due to deteriorating outcomes after entry. As the size of a firm becomes larger after entry, disadvantages in terms of product costs become lower, and smaller firms are more likely to survive competition against newcomers.

Through the empirical results, a positive correlation was found between the size of a firm and its survival probability. The survival rate of small-size firms can be more than doubled as firms grow and their business continues (Phillips & Kirchhoff, 1989), and in many industry fields, a reduction in the risk rate of newcomers was verified as the size of firms increased (Mahmood, 1992).

In contrast with the above claims that the larger the size, the better the survival, Agarwal and Gort (1996) and Agarwal (1996) suggested that the sizes of firms was negatively correlated with the survival of firms, and the direction of the relationship between business duration and the survival of firms was not unilateral. They used the market life cycle of products and extended business duration data to determine the decline point of firms, and found that after this point, the longer the business duration, the higher the drop-out rate.

There is another claim that the survival probability of firms is positively correlated with the size of firms at the early stages of industry evolution (Geroski, 1995; Sutton, 1997), but this effect disappears at the mature stage. At the mature stage, the window of opportunity to set the standardization of products through innovation activity closes, and the most likely method of entry at this stage is the finding of a strategic niche. According to the theory of strategic niches, a firm remains at a small size, but takes a niche that cannot be accessed by larger firms to generate profit as large as those larger firms are capable of producing (Caves & Porter, 1977; Porter, 1979). Due to the capabilities of small-size firms that look for such strategic niches, small- and large-sized firms in the same industry can coexist at the mature stages of the industry. In the mature stage of the cycle, the disadvantages due to their small scale experienced by smaller firms can be avoided through the strategy of taking a strategic niche. Therefore, the size of a firm may enable an advantage of reducing the possibility of failure at the earlier stages of industry introduction, but it may not have such advantages at the mature stage (Agarwal & Audretsch, 2001).

Study results have also suggested that not only the survival rate of firms, but also the growth of firms is positively correlated with the size of a firm. Studies on the relationship between the size and growth of firms follow the “zebra law,” that the probability to catch the next opportunity is correlated with the current size of a firm (Sutton, 1997). Such a relationship between the size and growth of firms is accepted as a formalized fact. It can be observed in a number of countries, such as the USA (Agarwal, 1997; Audretsch, 1991, 1995a; Audretsch & Mahmood, 1995; Dunne, Roberts, & Samuelson, 1988), Canada (Baldwin & Gorecki, 1998; Baldwin & Rafiquzzaman, 1995), Portugal (Jose Mata & Portugal, 1994; José Mata, Portugal, & Guimaraes, 1995), and Germany (Wagner, 1994).

Previous studies on the relationship between the size and survival rate of firms are presented in Table 3, in which whether each of the studies agrees with the formalized fact that the size of a firm affects its survival positively, and whether each of them followed the characteristics of each stage in the industry life cycle are presented.

3.2.2 Entry timing

There have been many attempts to verify whether the survival rate of firms can differ depending on the entry timing of firms into the industry. These studies tried to verify whether the First Mover Advantage is awarded to firms that entered the industry at the early stages of the industry life cycle, before the industry matured and many other firms join the industry. Most related studies produced the result that early entry was advantageous to a firm's survival (Audretsch, 1991; Cantner, Dreßler, & Krüger, 2006; Klepper & Simons, 2005; Lambkin, 1988).

The reasons for the high survival rate and the advantage of the early entry of firms suggested by the studies are as follows. Since early entry firms can acquire assets and secure purchasers earlier than others, a switching cost is incurred that prevents consumers from moving to other firms' products, so they have advantage of product and process technology over others (Lieberman & Montgomery, 1988). In addition, early entry firms can create a variety of entry barriers to ward off latecomers. Such entry barriers confer advantages onto early entry firms, making their survival more likely. With respect to the scale of firms, early entry firms can scale up their business before latecomers enter, making it difficult for latecomers to overtake the size of the early entry firms that enjoy the First Movers Advantage (Klepper, 1996). In addition, early entry firms may make entry barriers not only for their own survival, but also for growth (Bartelsman, Scarpetta, & Schivardi, 2005).

However, there is also a claim that Late Mover Advantage is present, depending on circumstances. Early entry firms may risk making design developments that will not later become the dominant design (Olleros, 1986). In addition, the disadvantages of early entry firms may occur, due to the tendencies of the free-rider effect and inertia (Lieberman & Montgomery, 1988). As the business duration increases, many innovations have been made, but discrepancies between organizational capabilities and demand requirements in the current environment will become larger disadvantageously. That is, although old organizations can innovate better than newly-created organizations, they risk the development of a disparity between what the market wants and what the organization is capable of providing (Sørensen & Stuart, 2000). In addition, early entry firms have a continuous challenge to overcome latecomers that enter with superior generic skills (Rothaermel & Hill, 2005; Shamsie, Phelps, & Kuperman, 2004). In addition, leading firms that enter the industry at an early stage may have spent all their energy in ceaseless technological and market creation, or suffered from the earlier-than-expected decline of the first generation of technology. That is, firms that enter an industry at the time when technology activities are predominant have a higher survival rate, because existing firms may suffer from their use of obsolete technologies (Agarwal, 1996).

Moreover, early entry firms may have survival advantages, because of either their environment or the time that they entered the industry. If information based on experiences that are not transferred is an important input factor in the creation of innovation activities, existing firms tend to have the advantage of innovation over latecomers. Furthermore, the accumulation of information through market experience by existing firms can be found easily in a more mature industry. However, if external information of routines performed by existing firms is an important factor in the creation of innovation activities, latecomers may have the advantage of innovation over existing firms (Agarwal & Audretsch, 2001).

A number of studies have reported that early entry firms' advantages change around the time of the introduction of the dominant design. In particular, Nelson (1995) claimed that early entry firms had no advantage, because accumulated knowledge is only effective after the dominant design has been selected. In addition, Dowell and Swaminathan (2006) said that although the advantages of early entry firms may be acknowledged to some extent, such an effect will only be effective before the dominant design, since the entry of firms after the dominant design is advantageous due to the resolution of such uncertainty. The above two claims may sound contradictory, but both can be re-interpreted according to the time of industry development as follows. Early entry firms are at an advantage until the dominant design appears, but the knowledge is initialized again as soon as the dominant design has been determined, so that the advantages of early entry firms disappear, whereas newly entered firms have a First Mover Advantage.

However, in contrast with a claim by Nelson (1995) that knowledge is initialized upon the dominant design's appearance, Suarez and Utterback (1995) accentuated that the experiences of creating product designs that are not chosen as the dominant design can also be advantageous. In addition, existing firms may have more advantages than newly entered firms in terms of their complementary capabilities such as learning ability, marketing, or logistics (Buenstorf, 2007; Rothaermel & Hill, 2005; Sosa, 2009).

Most studies acknowledge the existence of the First Mover Advantage, but skepticism over the First Mover Advantage has arisen in some more recently created industries. The technological advantages of early entry have been maintained in past industries, but such effects cannot be maintained in recent studies (Buenstorf, 2007) so the First Mover Advantage through information advantage cannot be enjoyed as much as in the early 1900s (Agarwal & Gort, 2001).

Previous studies on entry timing are presented in Table 4, in which whether each of the studies agrees with the formalized fact that the early entry of firm affects survival of firms positively, and whether each of them have followed the characteristics of each stage in the industry life cycle are presented.

3.2.3 Experiences prior to the entry

Studies related to experiences prior to entry are interested in the survival rate of *de novo* firms that have no experience in other related industries prior to the entry and *de alio* firms that have experience in related industries or enter by means of spinning off. Most previous studies have derived that the survival rate of *de alio* firms was higher than that of *de novo* firms. When radio manufacturers entered the TV manufacturing market, their survival rate was high (Klepper, 2002b) while the survival rate and achievements of firms that entered the computer hard disk industry through spin-off were higher than firms that entered without spin-off (Agarwal, Echambadi, Franco, & Sarkar, 2004). The survival rate of *de alio* firms in the automobile (Klepper, 2002a) and fashion industries were similarly higher (Wenting, 2008).

The reason for the claim that *de alio* firms have more advantages in the above papers is because experiences obtained from related industries are not only helpful but can also utilize complementary assets and networks easily. For example, experiences in logistics, distribution, or marketing areas can be advantageous factors in newly entered industries.

In addition, not only are the networks accumulated by firms beforehand advantageous for survival of firms, but also the network capabilities of firm owners. This is because firm owners who are can depend on wide and various ranges of personal networks and businessmen who can gain assistance from such networks are more likely to be successful (Persson, 2004). This supports the fact that a network of firms or business owners is likely to increase their survival rate.

However, in contrast with study results that have shown that *de alio* firms have survival advantages, claims that *de novo* firms are more able to survive than *de alio* firms can also be found. Khessina and Carroll (2008) claimed that the difference of new product development cycles is related to the difference of survival. This is because *de novo* firms tend to be able to be able to work faster in the cycle of new product development than *de alio* firms. This can be interpreted as there being more pressure on *de novo* firms to create a distinct identity in the market. In addition, it was explained that experiences in other related industries, as mentioned earlier, as advantages of *de alio* firms cannot be applied to every industry, as they are more dependent on technological characteristics and entry timing (Bayus & Agarwal, 2007).

There is another claim that the difference in survival between *de novo* and *de alio* firms can be found depending on a time in the industry life cycle. *De alio* firms have a lower risk rate in the early stages of the industry life cycle, but after the early stage, they have a higher risk rate compared to *de novo* firms. This is because *de alio* firms have high opportunity costs while they remain in the market (Agarwal, 1997). That is, *de novo* firms have no choice but to concentrate on the current industry, while *de alio* firms could be kicked out of the industry even if they are profitable but have a low earning rate compared to other new opportunities. However, it can be seen that *de alio* firms have advantages to their survival until the shakeout time.

Previous studies on experiences prior to entry are presented in Table 5, in which whether each of the studies agrees with the formalized fact that *de alio* firms affect survival positively and whether each of them follow the characteristics of each stage in the industry life cycle are presented.

3.2.4 Innovativeness

There is no disagreement with the concept that innovative firms are capable of long-term survival. Innovation is insurance against failure (Cefis & Marsili, 2006) and technological activity increases the chances of survival (Agarwal, 1996).

However, the assessment of innovation has been performed in empirical analysis in a great variety of ways. For example, the following assessment methods have been reported in previous studies: The level of adoption of the latest generation technologies (Lawless & Anderson, 1996); the level of adoption of the dominant design (Christensen, Suárez, & Utterback, 1998);

proximity to the leading technology (Fontana & Nesta, 2009); the adoption rate of radical manufacturing technologies and their application (Sinha & Noble, 2008); the number of patents produced per year (S. Wagner & Cockburn, 2010); the outcome of certification contests (Rao, 1994); and new product releases (Agarwal, 1998; Bonaccorsi & Giuri, 2001; Gort & Klepper, 1982; Greenstein & Wade, 1998; Haupt, Kloyer, & Lange, 2007). In addition, Gort and Klepper (1982) assessed the levels of innovation by dividing them into minor and major innovations with the help of experts through surveys, while other studies divided it thus: Innovation that destroys existing technological competences and capabilities, and innovation that enhances existing technological competences and capabilities (Tushman & Anderson, 1986). However, there have been no studies on the changes in innovation effects according to the stage in the industry life cycle among the studies into innovation.

Previous studies on innovation are presented in Table 6, in which whether each of the studies agrees with the formalized fact that innovation affects the survival of firms positively and whether each of them have followed the characteristics of each stage in the industry life cycle are presented.

3.3 Sub-conclusion

The following formalized facts are derived from the literature analysis. First, it was found that the larger the size of a firm, the higher its survival probability. Depending on the stage in the industry life cycle, the size effect may be weakened once the industry is stabilized after a shakeout, because strategies that utilize niche markets may be employed.

Second, with respect to the entry timing of firms, the earlier a firm enters an industry, the higher their general survival probability. This result is obtained because the early entry of firms can preempt information or distribution networks, and early entry firms have advantages in customer preemption. However, after a shakeout, early entry firms may feel fatigued due to their necessary continual innovation activities. In particular, after the dominant design appears, the knowledge that was accumulated by early entry firms may become obsolete, removing such early advantages. It should also be noted that any firm can chase the leading firm quickly through imitation in modern industry, so that the advantage effect of information, which was effective in the early 1900s, may not be the same as in the early 1900s. Therefore, it was suggested that the advantages of early entry firms may be lost in modern industries.

Third, it was found that the experiences of other related industries prior to entry helped an increase survival probability. This is because distribution networks, reputation, knowhow, and assets accumulated via related industries were helpful to the entry of a firm into a new industry. However, as competition becomes fiercer, profit margins become narrower. As a result, firms that perform business activities in other industries tend to get kicked out of the industry quickly in consideration of opportunity costs. In addition, firms that had no prior experience may find it difficult to survive, but once they have managed to survive, they tend to have better outcomes than firms with prior experience. This means that as an industry evolves, the chances of survival for *de novo* firms that have had no experience prior to their entry will increase.

Finally, with regard to innovation, there was no exception that all innovative firms had high survival probabilities. However, studies related to innovation did not provide differentiated results over time. Changes in the role of innovation over time cannot be understood via previous studies yet. Moreover, a more multidimensional approach is required for this study area rather than only considering simple innovation costs or the number of patents that have been produced.

These studies have limitations in terms of the following three viewpoints. First, most studies did not differentiate the stages in the industry life cycle so that they did not represent changes in technological uncertainty or technological regimes over the industry life cycle. In particular, studies on entry timing to industries and experiences prior to the entry showed different results according to the stage of the industry life cycle depending on used data. Therefore, a study on survival of firms requires analysis with a more fine division of the stages of an industry's life cycle.

As for the second limitation, most previous studies saw firms as entities that were passively selected, simply by the selection mechanism of markets. As discussed earlier, the adaptation efforts of firms are also considered when the selection mechanisms of markets are identified. Although the adaptation strategies of firms were considered in studies modeling the industry life cycle, most empirical analysis studies did not include the adaptation strategies of firms, except for studies related to innovation. Even studies related to innovation suggested only simple adaptation strategies that allowed firms to be innovative, while failing to consider various adaptation strategies related to technology.

Finally, studies related to innovation of firms were generally vague in assessing the innovation of firms and simplified assessment of innovation excessively. In particular, the number of patents produced may not be appropriate to analyze the early phase of an industry as a proxy variable of innovation. This is because the patent rate in a new industry is not high in many cases (McGahan and Silverman, 2001).

To overcome such limitations in identifying the selection mechanism at the shakeout period, the following elements are required. First, stages and changes in industrial environments according to the industry life cycle should be taken into consideration. Second, differences between recent and old industries should be taken into consideration. Third, adaptation strategies of firms should be considered in a multifaceted manner. Fourth, not only adaptation strategies of firms but also selection mechanisms in previous studies should be considered together.

Therefore, this study aimed to test the hypothesis that adaptation strategies and selection mechanisms differ according to time prior to a shakeout, time of shakeout occurrence, and time after shakeout.

To test this hypothesis, empirical analysis was conducted with regard to the US automobile industry in the early 20th century (Chapter 4) and mobile industry in the early 21st century (Chapter 5). Through this empirical analysis, it is expected to derive the law of survival within a framework of adaptation and selection in evolutionary economics. In addition, it is expected to provide effective strategic implications for firms to discover their roles proactively through application of the proposed method.

Table 3, Table 4, Table 5, and Table 6 show previous studies on sizes of firms, entry timing, experiences prior to the entry, and innovation, respectively. Each table includes authors and publication year of previous studies, (geographical) source and industry of data used, whether or not a study satisfies the formalized fact, and whether classification was done by criteria of the industry life cycle.

Table 3. Summary of previous literatures about the effect of firm size

Authors (Year)	Country	Industry	Stylized Facts	Period Classification
Dunne, Roberts, & Samuelson (1988)	US	Panel data	Positive	No
Phillips & Kirchhoff (1989)	US	Panel data	Positive	No
Audretsch (1991)	US	Panel data	Positive	No
Mahmood (1992)	US	High & Low Tech	Positive	No
Utterback & Suarez (1993)	US	TV, Typewriters, Transistor, Calculators	Positive	Yes
Jovanovic and MacDonald (1994)	US	Automobile	Positive	No
Jose Mata & Portugal (1994)	Portugal	Panel data	Positive	No
Wagner (1994)	Germany	Panel data	Positive	No

Audretsch & Mahmood (1995)	US	Panel data	Positive	No
Agarwal and Gort (1996)	US	25 products	Negative	Yes
Agarwal (1996)	US	High & Low Tech	Negative	Yes
Agarwal (1997)	US	Panel data	Positive	Yes
Pakes & Ericson (1998)	US	Panel data	Positive	No
Baldwin & Gorecki (1998)	Canada	Panel data	Positive	No
Agarwal & Audretsch (2001)	US	33 products	Positive	Yes
Klepper (2002)	US	Automobile	Positive	Yes

Table 4. Summary of previous literatures about the effect of entry timing to the market

Authors (Year)	Country	Industry	Stylized Facts	Period Classification
Willard and Cooper (1985)	US	TV	Positive	No
Olleros (1986)	Europe, US	Watch	Negative	No
Christensen and Rosenbloom (1995)	US	Disk Drive	Negative	No
Swaminathan (1996)	US	Beer	Positive	No
Henderson (1999)	US	PC	Positive	No
Sorensen and Stuart (2000)	US	Bio Tech., Semiconductor	Positive	No
Klepper and Simons (2000)	US	Tire	Negative	Yes
Klepper (2002)	US	Automobile, PC	Positive	Yes
Van Kranenburg et al. (2002)	Netherlands	Newspapers	Positive	No
Shamsie et al. (2004)	US	Household appliances	Negative	No

Rothaermel and Hill (2005)	US	PC, Steel, Telecom	Negative	No
Dowell and Swaminathan (2006)	US	Bicycle	Positive	No
Dowell (2006)	US	Bicycle	Positive	No
Kim and Park (2006)	Korea	Mobile Telecom	Positive	No
Boschma and Wenting (2007)	UK	Automobile	Positive	No
Buenstorf (2007)	Germany	Bicycle	Negative	No
Cantner et al. (2009)	Germany	Automobile	Positive	No
Agarwal and Gort (1996)	US	25 Products	Positive	No

Table 5. Summary of previous literatures about the effect of prior experience before entrance

Authors (Year)	Country	Industry	Stylized Facts	Period Classification
Holbrook et al. (2000)	US	Semiconductor	Positive	No
Klepper and Simons (2000)	US	TV	Positive	Yes
Klepper (2002)	US	Automobile, PC	Positive	No
Chesbrough (2003)	World	Disk Drive	Negative	No
Agarwal et al. (2004)	World	Disk Drive	Positive	Yes
Nerkar and Roberts (2004)	US	Pharmaceutical	Positive	No
Cattani (2005)	UK	Fiber optics	Positive	No
Klepper and Sleeper (2005)	US	Laser	Positive	Yes
Thompson (2005)	US	Shipbuilding	Positive	No
Klepper (2007)	US	Automobile	Positive	Yes

Boschma and Wenting (2007)	UK	Automobile	Positive	No
Buenstorf (2007)	Germany	Laser	Positive	No
Bayus and Agarwal (2007)	US	PC	Negative	Yes
de Figueiredo and Silverman (2007)	US	Printer	Positive	No
Madsen and Walker (2007)	US	Transport	Negative	No
Khessina and Carroll (2008)	US	Disk Drive	Positive	No
Wenting (2008)	World	Fashion	Positive	No
Simons and Roberts (2008)	Israel	Wine	Positive	No
Cantner et al. (2009)	Germany	Automobile	Positive	No
Buenstorf and Klepper (2009)	US	Tire	Positive	No

Table 6. Summary of previous literatures about the effect of firm's technological innovativeness

Authors (Year)	Country	Industry	Stylized Facts	Period Classification
Dowling and Ruefli (1992)	US	Telecommunications	Positive	No
Henderson (1993)	US	Photolithographic	Positive	No
Rao (1994)	US	Automobile	Positive	Yes
Lawless and Anderson (1996)	US	PC	Positive	No
Christensen et al. (1998)	US	Disk Drive	Positive	No
Tegarden et al. (1999)	US	PC	Positive	No
Roberts and Amit (2003)	Australia	Retail Banking	Positive	No
Jones (2003)	US	Semiconductor	Positive	No
Giarratana (2004)	US	Encryption Software	Positive	No
Roy and McEvily (2004)	US	Machine Tool	Positive	No

Wezel and van Witteloostuijn (2006)	UK	Motorcycle	Positive	No
Giarratana and Fosfuri (2007)	US	Security Software	Positive	No
Sinha and Noble (2008)	UK	Metal and Engineering	Positive	Yes
Cantner et al. (2009)	Germany	Automobile	Positive	No
Fontana and Nesta (2009)	Worldwide	LAN Switch	Positive	No
Wagner and Cockburn (2010)	US	Internet Service	Positive	No

Chapter 4. Adaptation strategies and selection mechanism in the US automobile industry

4.1 Empirical research of US automobile industry

Successful adaptation and selection mechanisms derived from previous studies summarized in the previous chapter are: high innovative firms, firms entering at the early stage of industry evolution, large size firms, and firms that had prior experiences in related industries. However, the above factors, other than innovation, are difficult to be changed at will by firms. That is, firms in previous studies are regarded as entities that are chosen passively by the market environment. Thus, previous study results have limitations in their ability to provide sound strategic implications for firms.

This is not to negate the fact that a firm is an entity chosen by the market mechanism. Rather, it asserts that adaptation efforts by firms shall be included in the analysis in addition to the selection mechanism. Firms have different backgrounds and experiences, so that each firm pursues a different type of innovation (Klepper, 1996). This means that there is extensive diversity in R&D

innovation and product level in newly created industries. It is also evident that a difference of prior experiences before the entry (Boeker, 1989; Carroll, Bigelow, Seidel, & Tsai, 1996; Holbrook, Cohen, Hounshell, & Klepper, 2000; Klepper & Simons, 2000) and/or a difference of decision making on how to create a business (Baron, Burton, & Hannan, 1999) also manifest differences in how to compete as well as in performance outcomes. In addition, trial and error of new entry firms may accentuate a difference in the market position (Dosi, 1982; Henderson & Clark, 1990; Tushman & Anderson, 1986). Therefore, it is necessary to include adaptation strategies of firms in the analysis.

Moreover, there are many other facts that cannot be explained by the formalized facts summarized in Chapter 3. For example, a claim that a large-size firm dominates a market overly simplifies a fact. However, with respect to the distribution of firm sizes, in reality, as a later stage of industry approaches, difference of scale is expanded and maintained thereafter (Coad & Rao, 2008; Malerba & Orsenigo, 1996).

There was an attempt to reflect the adaptation effort of firms before. In early days of related studies, some effort was made to consider heterogeneous adaptation strategies of firms. For example, a model proposed by Gort and Klepper (1982), which was regarded as the first attempt to model the evolution of industries, proceeded from the viewpoint of evolutionary economics by dividing a source of innovation into information from within an industry and information from outside that industry. Although a model based on the evolutionary economics reflected adaptation efforts of firms, such as accumulation of knowledge and absorption of knowledge from outside, to survive in their industry, it did not provide empirical results that reflected adaptation efforts of firms, since it circumvented the empirical analysis with the neoclassical economic analysis. A later model (Utterback and Suarez, 1993) also did not reflect the adaptation efforts of firms, because it saw that dominant design was given externally from the outside and firms just followed the trend. In other words, this model portrayed that firms that cannot acquire the dominant design are kicked out from the industry, thereby facing a shakeout; however, even firms that followed technologies other than dominant design can also have an ability to follow the dominant design through adaptation efforts. Nonetheless, such efforts of firms were not reflected in previous studies.

The reason for this failure of reflection of adaptation strategies in previous studies is due to difficulties in finding objective indicators or data that represent the adaptation strategies of firms. To resolve such a problem, this paper used a method that observes characteristics of products released by firms. This product analysis study approach has been used in a field of business administrative studies due to the characteristic of product analysis. However, firms are in contact with consumers through their products and, ultimately, survival of firms is decided by consumers' choice to the extent that they are most directly related to the operating principle of the market. Therefore, this study aimed to refine the characteristics of products released by firms into variables of firm level, thereby identifying the adaptation efforts of firms. Through this attempt, this study aimed to identify objective variables of adaptation strategies from the technological viewpoint of firms.

This chapter aims to identify adaptation strategies from the technological viewpoint by utilizing of product-level data released by firms and determine the effect of the identified adaptation strategies on survival of firms at the shakeout period to overcome the limitations of previous studies. In addition, this chapter also discusses interactions between factors that influence the survival of firms identified via previous studies and adaptation strategies.

Through this study, it is expected to disclose the selection mechanism at the shakeout period in consideration of adaptation strategies of firms in order to identify strategic implications that can be applicable to firms.

In Section 4.2, adaptation strategies are identified through study design and hypothesis setup and detailed study hypotheses are presented. In Section 4.3, a methodology that converts data of product level into adaptation strategy variable of firm level is explained along with the analysis model. In Section 4.4, empirical analysis results using the USA automobile industrial data in the early 20th century are presented. In Section 4.5, a summary and implications of Chapter 4 are presented.

4.2 Study design and hypothesis

4.2.1 Analysis of product level

It is not an easy task to observe adaptation strategies of firms. In particular, this difficulty is aggravated in studies related to evolution of an industry. This is because a long period of time passes from industry creation to maturity and, thus, a relatively long history is prerequisite for an industry to be analyzed. For this kind of analysis, financial data of firms is likely to be insufficient, and a survey-based approach is impractical. To overcome this limitation, the present study employed product data released in the past. Through this method, it is expected to derive adaptation strategies of firms in a more objective manner.

As such, not only does use of product data address the insufficient data problem, but also the product itself has an important role in a market. First, products play an important role in connecting markets and firms. If products are not accepted in a market, the corresponding firm is likely to be kicked out from the market. That is, firms are competing with one another through products. Furthermore, products play a great role in proposing a number of theories. Competition between products provided a foundation on which the strategic management theory was based (Porter, 1979) as well as providing core issues of theories concerning buying in transaction cost economics (Williamson, 1975). Products also play an important role in the industry life cycle in this study (Klepper, 1996).

However, there has been no study on the analysis of industry evolution by utilizing microscopic data at the product level, while the analysis of product level has been studied within a framework of business administration (Carroll, Khessina, & McKendrick, 2010). Therefore, it is expected that this study will play an important role as an interdisciplinary study that connects business administration and economics.

In the next section, a number of adaptation strategies are explained through products of firms.

4.2.2 Technological level of firms

As discussed in Chapter 3, studies on technological level or innovation of firms had limitations with respect to the assessment of technological level of firms. For example, existing studies presented R&D cost, the number of patents, or survey with experts, which only represented some effort of technology innovation, rather than assessment of technological level. Such variables are only indirect indicators if the variables are not applied to real products. Therefore, the present study aimed to assess technological level of firms directly by utilizing product-level data.

The above-mentioned previous studies related to innovation showed that high innovative firms had a high survival rate. In this regard, it is expected that technological level would be in a positive correlation with survival of firms while it would be in a negative correlation with an exit rate of firms.

According to a theory proposed by Klepper and Simons (2005), the reason for the survival of early entry firms at the shakeout time was because firms performed innovation using the early entry advantage. However, as firms stay longer and longer, malfunction of their structure and process can be found more and more to induce political internal division, redundant organizational routines, or malfunctioning departments (Carroll & Hannan, 2000). As a result, firms that entered later may be more innovative than early entry firms. In addition, early entry firms may also be threatened by firms that entered later with more advanced general-purpose technologies (Rothaermel & Hill, 2005; Shamsie et al., 2004). Accordingly, technological advantage of early entry firms is expected to be valid only until Phase I or Phase II. Therefore, the effect may disappear in Phase III; that is, the technological advantage of firms that entered later is expected to be advantageous to survival of firms.

4.2.3 Technology increase rate of firms

The Red Queen effect (Barnett & Hansen, 1996) in organizational evolutionary theory refers to the principle that a firm is left behind in competition in a relative sense, even if a firm performs innovation but the competitors and surrounding environment perform better innovation. The name of this effect is derived from *Alice in Wonderland* in which people in the Red Queen's kingdom cannot move forward because the surrounding environment is also moving together with them. Leigh Van Valen (1973), an evolutionary theorist, employed this term to express a chasing and being chased parallel relationship in the ecosystem. This phenomenon refers to a situation in which even if a firm has a high technological level, that firm can be overtaken by competitors at any time if it exhibits low technological growth.

In addition, products in the early stage are primitive in general, so the willingness to pay is low (Agarwal & Bayus, 2002). Therefore, it is expected that a technological increase rate in Phase I could be more important than a technological level itself. The reason for this is because the dominant design is not yet established, and most products are unlikely to meet the consumer's requirement in terms of technological level at this stage. Therefore, consumers are likely to be affected more by the technological increase rate than technological level itself.

Furthermore, organizations are always learning. Firms should keep learning how to survive in a fierce competition that is particularly pronounced in the early stage of an industry. Moreover, firms can survive when they respond actively to changes in industrial environment and other competitors. To achieve this, firms operate processes for adaptation. In this regard, technological increase rate is expected to be an important factor for survival of firms in Phase I.

4.2.4 Product dispersion of firms

This subsection aims to analyze how the difference in adaptation strategies generalist and specialist firms is displayed according to the evolutionary stage of the industry via the product dispersion strategy of firms. In general, generalist firms tend to be suitable for stable environment, while specialist firms are suitable for rapidly changing environment (Utterback & Suarez, 1993). However, the above result may be overturned if an entry timing of the dominant design is considered in the industrial evolution stages. That is, when various products are manufactured, a risk-diversification effect may be obtained, though capability cannot be focused and it is difficult to imprint specialized images of products on the consumer's mind. Early entry firms at the early stage compete with one another to dominate product design. Although it is unlikely to occur, success leads to a high growth rate. Therefore, a risk-diversification strategy that increases the probability of the product to be included in the dominant design by releasing a variety of products will be effective at the early stage of industry evolution; however, after the dominant design appears, specialist firms that are focused on the dominant design will be advantageous.

In contrast, the window of opportunity to set the standardization of products through the innovation activities will be closed at the mature stage. This is because radical innovation is less prevalent in the entry at the mature stage, which aims to take a strategic niche (Newman, 1978; Porter, 1979). Under such circumstance, specialist firms are expected to enjoy a survival advantage.

4.2.5 Product differentiation of firms

A product differentiation strategy of firms plays an important role in adaptation strategies, too. This strategy can be broadly divided into two: a strategy that concentrates on a niche market and a strategy that imitates the dominant design of an industry. Since the dominant design is already formed in the shakeout period, an imitation strategy may be more effective. It is also true that since the dominant design is forming at the early stage of industry evolution, it would be advantageous to imitate products in the product family that is likely to become the dominant design by identifying the trend of other firms. However, it would be advantageous to develop unique images by attempting product differentiation at a later, stabilized, stage of industry evolution.

Such an effect may be more evident at the later stage of industry evolution depending on the firm size. It has been asserted that once the dominant design is established, only the mature stage of industry evolution can witness co-existence of small and large size firms in the same industry at the same time thanks to capability of small size firms that take strategic niches (Caves & Porter, 1977; Newman, 1978). That is, according to the theory of strategic niche, a firm remains small but inhabits a niche that cannot be accessible to larger firms. In the mature stage in the cycle, disadvantages due to small size experienced by small companies can be overcome through the above strategy, which targets the strategic niche. Therefore, where firm size is small, a product differentiation strategy is expected to be advantageous to survival in the Phase III period.

In addition, a product differentiation strategy may affect the survival of firms differently depending on the entry timing. Due to the preemptive excessive density of existing firms, new entry firms are forced to release their products in a surrounding empty space. Moreover, firms that entered later generally employ a strategy focused on a single market segment (Bonanno, 1987; Schmalensee, 1978). Existing firms place their products near existing products in general; however, once their products are threatened by new entry firms, existing firms tend to locate their products far away from the dense area (Stavins, 1995). Therefore, it would be advantageous to latecomers' in the late stage of industry evolution survival if they employ a product differentiation strategy.

4.3 Analysis model

4.3.1 Survival analysis

Survival analysis was conducted using the Cox Proportional Hazards Model with Time Varying Covariates (Cox, 1972). The Cox proportional hazards model is a widely used method to analyze risk factors that influence the survival of firms. This model is non-parametric in the sense that it does not assume any kind of distribution type with respect to a survival time, whereas this model is parametric in the sense that the regression coefficient is estimated.

The Cox proportional hazards model has many benefits in analysis of survival data of firms. The survival data in the survival analysis is composed of data from a certain set starting point to an occurrence point of event. Unlike statistics that deal with continuous variables, the survival data should take not only survival time but also occurrence of event into consideration simultaneously. Moreover, since the survival data does not follow a normal distribution, it cannot be analyzed using a general regression model. If a Probit or Logit model, which used an occurrence of event as a dependent variable, is used, then a survival time cannot be considered at the same time. In the survival analysis, interrupted data is not excluded from the analysis but is utilized to obtain a baseline hazard, which is advantageous due to the use of interrupted data. For example, even in cases where the event did not occur within the analysis period or there is a failure to trace whether an event occurred or not, such data is not excluded from data analysis. In addition, the Cox proportional hazards model with time varying covariates can include time varying covariates so that dynamic analysis can be possible.

A hazard function is shown in Equation (4.1), while a hazard function at time t represents a conditional probability that a firm that survived up to time t for T duration is dead immediately after time t.

$$h(t) = \lim_{\Delta t \to 0} \frac{P(t \le T < t + \Delta t \mid T \ge t)}{\Delta t} \qquad (4.1)$$

The basic model of the Cox proportional hazards model at time t is shown in the following Equation (4.2). Here, $h_0(t)$ refers to a baseline hazard function, in which values of all independent variables are equal to 0. x_k is an independent variable that influences survival duration, T . It is interpreted with respect to β_k that whenever x_k increases by one unit, a risk level increases by $\exp(\beta_k)$ times.

$$h(t) = h_0(t)\exp(x_1\beta_1 + \cdots + x_k\beta_k) = h_0(t)\exp(x'\beta) \tag{4.2}$$

If time varying covariates are included in the basic Equation (4.2), the Cox proportional hazards model with time varying covariates will be given by Equation (4.3). x_j represents a characteristic that does not change over time, while x_{it} represents a characteristic that changes over time. A likelihood function with respect to time $t_1, \cdots, t_d$ is shown in Equation (4.4).

$$h(t, x) = h_0(t)\exp(x_j\beta_j + \cdots + x_{it}\beta_i) \tag{4.3}$$

$$L(\beta)=\prod_{i=1}^{d}\frac{\exp(\beta x_{it})}{\sum_{k\in R_{it}}\exp(\beta x_{kt})} \tag{4.4}$$

In this paper, data is divided according to the division of the industry life cycle stage, and variables that influence survival in each stage are derived. For the analysis, survival durations of all firms are re-set on the basis of a starting point of a corresponding analysis period. A method of how to divide the industry life cycle stage is described in detail in a later section.

The Cox proportional hazards model used for the analysis is shown in Equation (4.5).

$$\begin{aligned} h(t) = h_0(t)\ \exp\{&\beta_1 \times Size\_dummy_i \\ &+ \beta_2 \times First\_mover\_dummy_i \\ &+ \beta_3 \times Technology\_level_{it} \\ &+ \beta_4 \times Technology\_growth_{it} \\ &+ \beta_5 \times Product\_dispersion_{it} \\ &+ \beta_6 \times Product\_difference_{it}\} \end{aligned} \tag{4.5}$$

$Size\_dummy_i$ represents size of a firm, while $First\_mover\_dummy_i$ represents an early entry firm. $Technology\_level_{it}$, $Technology\_growth_{it}$, $Product\_dispersion_{it}$, and $Product\_difference_{it}$ refer to technological level, technological increase rate, product dispersion, and product differentiation variables, respectively, and they change over time. The first two variables, which are derived via previous studies, are ones that influence survival of firms, while the latter four variables are ones that represent adaptation strategies of firms. The reason for processing size of firm as a dummy variable is to have consistency with respect to the second analysis in which adaptation strategies might differ by size of firm. Note that a dummy variable was used to represent a size variable to make it easier to understand the meaning. How to derive variables and used data will be explained in more detail later.

The second empirical analysis aimed to determine the relationship between each adaptation strategy variable and formalized facts disclosed through the previous studies, which were conducted to find out how the effect of adaptation strategy can differ by firm size. Equation (4.6) is a survival analysis model according to size, which includes a size dummy and interaction term of each strategy variable.

$$
\begin{aligned}
h(t) = h_0(t)\ \exp\{ & \beta_1 \times Size\_dummy_i \\
& + \beta_2 \times First\_mover\_dummy_i \\
& + \beta_3 \times Technology\_level_{it} \\
& + \beta_4 \times Technology\_level_{it} \times Size\_dummy_i \\
& + \beta_5 \times Technology\_growth_{it} \\
& + \beta_6 \times Technology\_growth_{it} \times Size\_dummy_i \\
& + \beta_7 \times Product\_dispersion_{it} \\
& + \beta_8 \times Product\_dispersion_{it} \times Size\_dummy_i \\
& + \beta_9 \times Product\_difference_{it} \\
& + \beta_{10} \times Product\_difference_{it} \times Size\_dummy_i \}
\end{aligned}
\tag{4.6}
$$

The third empirical analysis aimed to determine whether there is a difference of effect by the adaptation strategy between early entry firms and the other firms, such that survival analysis was conducted by using an early entry dummy as an intersection term. A survival analysis model according to the entry timing is shown in the following Equation (4.7).

$$
\begin{aligned}
h(t) = h_0(t)\ \exp\{&\beta_1 \times Size\_dummy_i \\
&+ \beta_2 \times First\_mover\_dummy_i \\
&+ \beta_3 \times Technology\_level_{it} \\
&+ \beta_4 \times Technology\_level_{it} \times First\_mover\_dummy_i \\
&+ \beta_5 \times Technology\_growth_{it} \\
&+ \beta_6 \times Technology\_growth_{it} \times First\_mover\_dummy_i \\
&+ \beta_7 \times Product\_dispersion_{it} \\
&+ \beta_8 \times Product\_dispersion_{it} \times First\_mover\_dummy_i \\
&+ \beta_9 \times Product\_difference_{it} \\
&+ \beta_{10} \times Product\_difference_{it} \times First\_mover\_dummy_i\}
\end{aligned}
\tag{4.7}
$$

4.3.2 Division of time by shakeout

A way to divide a stage in the industry life cycle followed the three-phase division proposed by Dinlersoz and MacDonald (2009). As explained earlier, this paper is focused on a shakeout, so the use of three-phase division such as prior to, during, and after shakeout time is appropriate for the purpose of this study. This division has a distinctive advantage since the peak time of the number of total firms entered is divided into Phase I and Phase II. Therefore, a beginning of Phase II, which represents a start time of shakeout, was classified on the basis of a time when the number of total firms entered was the maximum. One way to divide the industry life cycle in general is by checking a graph above all other methods rather than using a quantitative way (Dinlersoz & MacDonald, 2009; Gort & Klepper, 1982). Therefore, Phase III was selected as a time when a net entry was converged to 0 as a change in trend was observed according to the definition of Phase III, in which a net entry was nearly close to 0. To resolve the ambiguity of the division of time, later sections will explain more about historical events at the time. Here, historical events are briefly summarized. The first conveyer transfer method was employed in the Model T of Ford released in 1908, followed by a wide adoption of this method by other companies. As a result, many companies that could not meet the low price were kicked out of the industry, creating a shakeout. Due to the success of this, the market share of Ford increased to more than 50%. However, GM achieved a top market share for the first time in 1927 through full line and model change strategies, which were competing against the low price product strategy of a single product of GM. Then, the Big Three of the US automobile industry were established with the entry of Chevrolet, which aimed at customers in a middle layer between Ford and GM. Then, since 1927, there has been no significant change in a market share of US car industry for 87 years, which was regarded as the stabilization period. Therefore, the year of 1927 can be seen as the beginning of an industry stability period.

4.3.3 Technology assessment of products using the Hedonic price model

Prior to the identification of adaptation strategies by firm level, it is necessary to identify the technology level of their products. However, this analysis is difficult because a product is composed of many various attributes. To simplify the attributes of a product with multidimensional characteristics into a single indicator, the hedonic price model has been most popular (Combris, Lecocq, & Visser, 1997; Griliches, 1961).

The hedonic price model assumes that the value of goods and services are determined by the characteristics contained in those goods or services (Rosen, 1974). That is, the model assumes that consumers buy a bundle of characteristics contained in goods or services. Equation (4.8) shows a general equation of the hedonic price model with respect to products (Fontana & Nesta, 2009; Stavins, 1995).

$$P_{mit} = \sum_{j} \beta_j z_{jm} + \alpha_t + \mu_t + \varepsilon_{mit} \tag{4.8}$$

P_{mit} is an indexed value of time t, firm i, and price of product m, which uses a deflated value; z_{jm} represents the j-th technological characteristic of product m, which is also indexed as same as in the case of price. In addition, β_j represents a hedonic price or potential price. μ_t and α_t represent a firm dummy at time t and a year dummy at time t, respectively.

A technology level was calculated by multiplying $\hat{\beta}_j$ estimated through regression of the hedonic price model and technological factor of each product. For example, if horsepower and fuel efficiency of a vehicle are used as technological factors, potential prices increased by one unit of horsepower and one unit of fuel efficiency are derived by the regression result. A price in terms of technological viewpoint is derived by multiplying these two prices. That is, assuming that T_{mit} is a technology level of product m of company i at time t, a technology level is expressed by Equation (4.9). The price-related strategic characteristic by manufacturing company is not included in technology and is, thus, the effect due to manufacturing company is excluded.

$$T_{mit} = \hat{p}_{mit} - \mu_i \qquad (4.9)$$

A technology level derived through the hedonic price model represents a technology level in a product level. Therefore, an additional process is needed to derive variables in a firm level.

4.3.4 Adaptation strategy variables of firms

The adaptation strategy variables of firms use indexes in a product level derived in terms of technological viewpoint, as explained in the previous subsection. In this subsection, a procedure and method that can derive outcomes at a firm level are explained using data in a product level. Therefore, all variables derived in this subsection refer to variables in a firm level.

4.3.4.1 Technological level of firms

A firm releases various products every year; however, in this study, the product of the highest technology level was defined as the technology level of a firm. Nonetheless, technological advancement occurs at a fast pace every year so that a technology level of an old product should be relatively low. Therefore, technology level was divided by the highest technology of the entire industry at a corresponding year. As a result, $Technology\_level_{it}$ of firm is within a range of 0 and 1, which is expressed by Equation (4.10). $\max(T_{it})$ refers to the highest level of a product manufactured by company i at time t, while $\max(T_t)$ refers to the highest-level product in the entire industry at time t. Technology level of firm and technology improvement rate, which will be explained in the next subsection, are used based in part on study by Fontana and Nesta (2009).

$$Technology\_level_{it} = \frac{\max(T_{it})}{\max(T_t)} \tag{4.10}$$

4.3.4.2 Technology improvement rate of firms

Technology improvement rate of firms means the increase rate of technological level of a firm derived in the above. Technology improvement rate was calculated by dividing a technology level increased from time $t-1$ to t by a technology level at time $t-1$. Note that when a product of the highest technology level was exited and a new product not released, this value may have a negative value, as expressed in Equation (4.11).

$$Technology\_growth_{it} = \frac{Technology\_level_{it} - Technology\_level_{it-1}}{Technology\_level_{it-1}} \tag{4.11}$$

4.3.4.3 Product dispersion of firm

The product dispersion variables of firms followed a method used in Feenstra and Levinsohn (1995). In previous studies, these variables were used to verify whether there was a difference of dispersion of product between existing and newly entered firms.

$Product\_dispersion_{it}$ refers to how widely products of a firm are dispersed in a market. Since product dispersion tends to increase over time, dispersion in an industry level was considered only in this study. A level of dispersion at the firm level can be expressed by Equation (4.12). A level of dispersion at an industry level is expressed by Equation (4.13), while $Product\_dispersion_{it}$, derived by dividing Equation (4.12) by Equation (4.13), is shown in Equation (4.14).

$$\sigma_{it} = \frac{\sum_{m=1}^{M_{it}} (T_{mit} - \overline{T}_{it})^2}{M_{it}} \quad \text{such that} \quad \overline{T}_{it} = \frac{\sum_{m=1}^{M_{it}} T_{mit}}{M_{it}} \tag{4.12}$$

T_{mit} refers to a technology level of product m manufactured by company i at time t, while $\overline{T}_{it}$ refers to a mean technology level of firm, which is calculated by a sum of all technology levels of all products released by company i at time t by the number M_{it} of products released by company i at time t. σ_{it} refers to a dispersion level of company i at time t, which indicates the distances of all products released by company i at time t from the mean technology level of firm. To precisely calculate a distance, a square root should be used. However, since it represents a rate of dispersion level of firm to a dispersion level of industry, there is no difference between them in terms of actual outcome.

As explained earlier, as a market grows, a dispersion level can be changed. Therefore, a dispersion level of the entire industry was calculated first as follows, and then compensated for using a rate of dispersion level between firm and industry.

$$\sigma_t = \frac{\sum_{n=1}^{N_t} (T_{nt} - \overline{T}_t)^2}{N_t} \text{ such that } \overline{T}_t = \frac{\sum_{n=1}^{N_t} T_{nt}}{N_t} \quad (4.13)$$

As in the above equation, T_{nt} refers to a technology of product, n, manufactured by company i. A mean technology level of industry was then calculated by dividing it by the number of total products existing in the industry, N_t, and then a mean distance of all products existing at time t is calculated. A dispersion level of industry derived using the above method is equivalent to σ_t. Dispersion level σ_{it} of firm level derived above is divided by a dispersion level σ_t of industry level, thereby deriving $Product\_dispersion_{it}$ as expressed in Equation (4.14).

$$Product\_dispersion_{it} = \frac{\sigma_{it}}{\sigma_t} \tag{4.14}$$

4.3.4.4 Product differentiation of firms

There are two methods to assess product differentiation. One is a method of using a minimum distance between products (Jeoung, 2003), and the other is a method of assessing a mean distance to all products (Stavins, 1995). A method of using a minimum distance between products is advantageous to a study on benchmarking strategy for a single product. However, since this method targets only a single product, it is difficult to derive outcomes at a firm level. For example, if there is only a single product in a niche market and a firm releases a similar product, it would be appropriate to see this as a niche market strategy. Therefore, this study follows the method of Stavins (1995) because it aims to identify a trend in a firm level. A firm will decide whether they release a product in a market that has no product currently by referring to past products, or release a new product in their main product family. The former means a strategy that pioneers a niche market, while the latter means an imitation strategy. In other word, the latter can be interpreted as following the dominant design. For this strategy, a comparison between products released at time $t-1$ and products released at time t is required. Equation (4.15) represents a differentiation level of product m manufactured by company i at time t.

$$Product\_difference_{mit} = \frac{\sum_{n=1}^{N_{t-1}} \sqrt{(T_{mit} - T_{nt-1})^2}}{N_{t-1}} \tag{4.15}$$

N_{t-1}, T_{mit}, and T_{nt-1} refer to the number of products at time $t-1$, technology level of product m manufactured by company i at time t, and technology level of product n at time $t-1$, respectively. It refers to a mean distance between N_{t-1} products existing at time $t-1$ and product m released at time t by company i. A mean is calculated by dividing a product dispersion variable of product m released by company i at time t by the total number of products released by company i at time t, M_{it}, hereby deriving $Product\_difference_{it}$, a product differentiation level of company i at time t. This is expressed in Equation (4.16).

$$Product\_difference_{it} = \frac{\sum_{m=1}^{M_{it}} Product\_difference_{mit}}{M_{it}} \quad (4.16)$$

4.4 Empirical analysis

4.4.1 The US automobile industry

The birthplace of the car was Europe. This is because Europe started the first research on internal combustion engines and transmissions that are smaller and lighter than steam engines. A German named Nicholas Otto tested and manufactured a 2-cycle engine in 1878; based on this engine, two men named Benz and Daimler successfully manufactured the first car with an internal combustion engine. Then, Benz founded an automobile manufacturing factory in 1886 and produced their own-designed three-wheel vehicles for the first time.

However, France was the first nation to accept cars. The noble class of Germany disrespected a new technology as they kept their traditional value, whereas France was open-minded on new technologies such as the car. That is, Germany developed cars while France created a market, creating a condition in which the nascent automobile industry could emerge.

There was demand for cars in the high classes in Europe with relatively good road conditions for the time. On the other hand, the USA is a huge country, and their road condition was bad except for in several large cities. Thus, the automobile industry in the USA started later than in Europe. The first general-purpose car in the USA was the Curved Dash from Oldsmobile in 1901, and the Model A was released by Ford in 1903. Although the USA entered the automobile industry later than Europe, it was able to accelerate the development of their automobile industry because of their mass production technology advancement.

The contributions to the US automobile industry development were thus thanks to the conveyor belt system of Ford and the release of Model T. The mass production via the conveyor belt system could produce a large of number of cars in a cost effective manner. This system affected the world automobile industry significantly beyond the USA automobile industry. Cadillac also manufactured a variety of cars, starting from cars with single cylinder engines in 1905 to luxury cars with four-cylinder engines. Then, Cadillac merged with GM and became the archetypical luxury car. Behind the success of Cadillac was part compatibility, which was a basis of the mass production system. In fact, behind the conveyor belt system of Ford, the achievement of Cadillac of part compatibility was the main reason of the success of Ford.

The Model T of Ford is an important milestone in the US automobile history. The Model T, first introduced in 1908, was equipped with a water-cooled, 4-cylinder, 2,896 cc, 20 horsepower engine and manufactured via the conveyor line of Ford for the first time. An average car price then was more than $2,000, but the Ford T was priced just at $950 and reduced to $290 by 1927 thanks to continuous price reduction. On the strength of this, Ford concentrated on Model T production, and its market share reached 50%, selling more than 15 million cars until it began to be phased out in 1927.

The success of Ford ignited an introduction of the conveyor system throughout the US automobile industry. Thanks to this, the USA annual automobile production was 187,000 cars in 1910 then 2.227 million cars in 1920, a ten-fold increase in just 10 years. As a result, the USA then accounted for more than 90% of the world automobile production.

However, as the US average household income improved, GM started challenging the Ford Model T, which was manufactured with only black color due to price reduction, by releasing a variety of new models of cars consecutively. Then, Ford, which had never lost its top market share from 1906 to 1926, gave up the lead to GM in 1927. GM then retained its preeminent position for 76 years. After this, Chrysler that released six-cylinder and four-wheel vehicles targeting middle layer customers between Ford and GM, forming so called Big Three of the US automobile industry. Then, the US automobile industry entered into a stabilization period without any change in ranking.

4.4.2 Data and variables

4.4.2.1 Data

The US automobile industry data was used to determine the effect of the adaptation strategies of firms on survival of firms at the time of shakeout. This study utilized data of product level in order to derive adaptation strategies of firms. Therefore, this study used automobile product data from 1905 to 1943. A total of 474 firms were included in the analysis period, with a combined 21,337 vehicle models. The Old Car Reference Library data provided by the Classic Car Database was utilized. The data includes product performance data of 61 areas such as release time, price and horsepower at the release time, the number of cylinders, wheel base, engine volume, and size of wheel. Vehicles driven by steam engines and electricity were found in the analysis period, but they were removed due to significant differences of technological criteria. In addition, only US-based firms were included in the analysis. This was because the proportion of imported cars in the USA was considerably small during the analysis period (Feenstra, 1988) and overseas-based firms may distort the survival analysis.

Since the above data did not contain information about firms, size of firm was obtained using the yearly production volume data of firms provided by Peiler (2004) and yearly passenger car production volume in the US provided by the U.S. Census Bureau to calculate market share in comparison with production.

With respect to experience variables prior to entry, some firms had prior experiences in bicycles and wagons industries before entering the automobile industry; however, these were not used for the analysis due to an insufficient amount of data.

The automobile industry is a traditional manufacturing industry, which had a clear shakeout. Thus, it was considered to be appropriate to test the hypotheses in this paper. In addition, the automobile industry is classified as a machinery industry and has had (and still has) ramifications for the whole economy as a key industry (Klepper, 2002a).

The following Figure 3 shows changes in entry, exit, and the total number of firms over time. In this figure, division of time according to the three-phase classification of Dinlersoz and MacDonald (2009) was shown, as explained in the previous section. Phase I and Phase II were divided on the basis of time when the number of firms was the largest, while Phase II and Phase III were divided on the basis of a time when net entry was converged to 0. Figure 4 shows change in net entries per year in the automobile industry. Accordingly, Phase I was set to the time up to 1911, while Phase II was between 1912 and 1927, and Phase III was from 1928 to the last year. The number of firms increased in some years of Phase II when a shakeout occurred, which was a unique characteristic of the automobile industry. However, to the best of the present author's knowledge, no previous study has mentioned this phenomenon. Nevertheless, this phenomenon may be explained in part by looking closely into the characteristics of the automobile industry. After the dominant design is established, changes in production methods such as factory facility replacement are required to produce products that follow the dominant design. Still, the automobile industry requires a broad range of changes in not only production lines but also in related parts industries. Therefore, it was likely to delay the ramification of the introduction of the dominant design due to this wide range of change requirements. Given this delay effect, the short stabilization period during the shakeout time might occur. In addition, the ambiguity of the dominant design felt by firms at that period may also be an indirect part of the reason for the retrograde period of shakeout.

There were two positions regarding the dominant design in the automobile industry. Since the dominant design is not clearly defined yet, it cannot be concluded that neither of the positions is wrong. One position is to see the dominant design on the basis of All Steel and Closed Body car manufacturing in terms of technological elements so that the dominant design started from the year of 1923 (Suarez & Utterback, 1995). The other position is to see the dominant position as conferred by market dominance, in which case the dominant design started from 1908 when the Ford Model T was released. The Ford Model T was sold from 1908 to 1927 for 18 years, selling 15 million cars (O'Hearn, 2007). This product is regarded as having pioneered the US automobile industry. Therefore, the dominant design was created gradually since the successful product was introduced in the market until the technically unified standard was set up. Thus, it was possible to see the shakeout phenomenon in an unconventional manner.

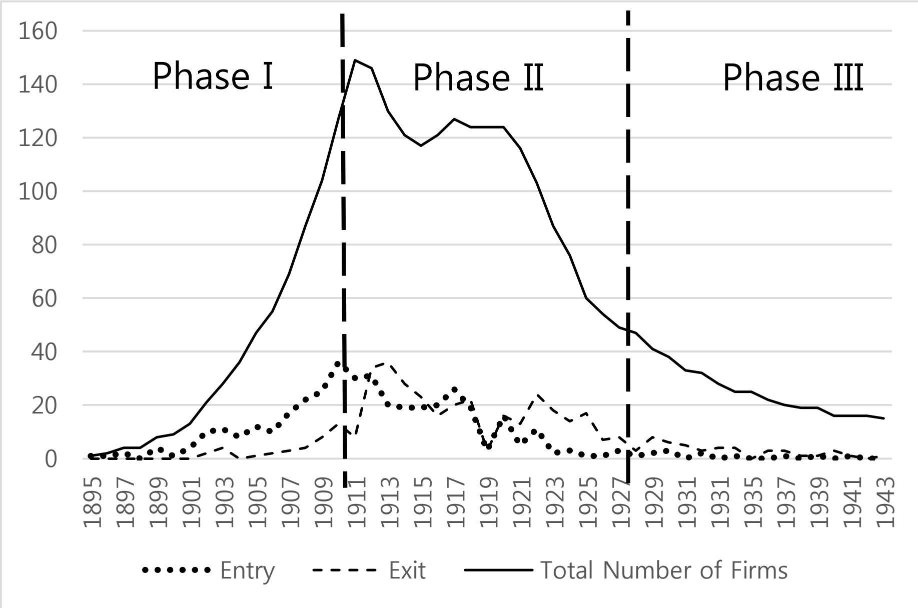


Figure 3. The number of exit and entrance firms in automobile industry

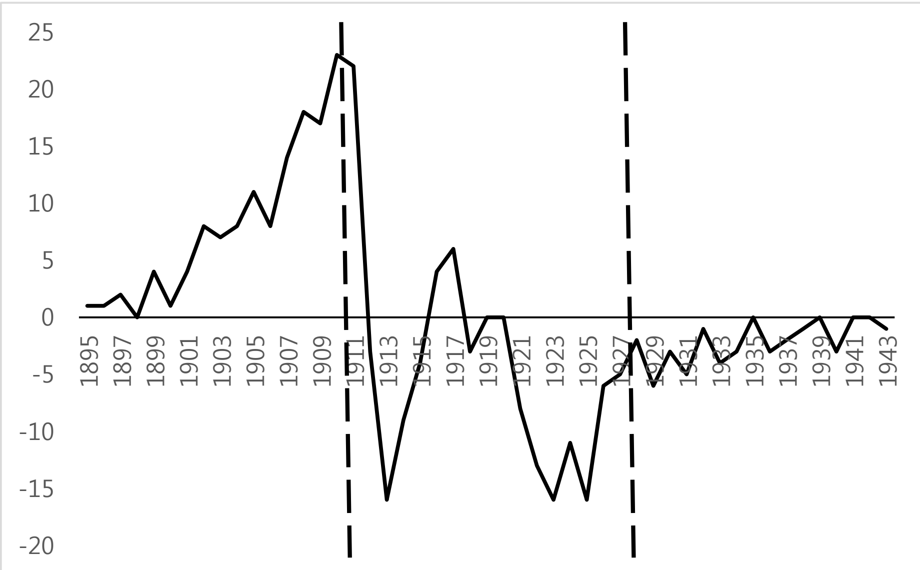


Figure 4. The change of net entry in automobile industry

4.4.2.2 Variables

As explained above, performance data of products will be indexed through the hedonic price model before adaptation strategy variables are derived. The basic statistical data of variables used in the hedonic price model are shown in Table 7. As an index to represent automobile performance, horsepower, Bore/Stroke ratio, the number of main bearings, size of tire, and the number of seats were set. Among 62 variables included in the data, many had a high correlation with each other, so that some variables to be used were limited. For example, horsepower and engine volume had a high correlation with each other, as more difference was generated in engine horsepower by the increase of engine volume rather than changes in efficiency due to technological advancement. Accordingly, only horsepower was used for the analysis. Correlations of the technological characteristic variables used are presented in Table 8.

There were considerable differences found compared to variables used in modern cars. For example, no technological characteristic concerning fuel efficiency was defined in the early 1990s because fuel efficiency was not regarded as important, whereas main bearings were regarded as important at that time and, thus, were included in the analysis. The analysis result of the hedonic price model is shown in Table 9. R^2 was 0.9061; thus, the explanatory power seems sufficient.

Table 7. Descriptive statistics of variables related to technology and attributes of automobile

Variable	Mean	Std. Dev.	Min	Max
(1) Horsepower (HP)	67.387	39.096	1.5	320
(2) B/S ratio	0.747	0.100	0.5	1.333
(3) Main bearings	4.347	1.800	2	9
(4) Tire size (cm)	71.427	19.480	30.480	113.034
(5) Number of passengers	4.599	1.638	1	10

Table 8. Correlation table of variables related to technology and attributes of automobile

	(1)	(2)	(3)	(4)	(5)
(1) Horsepower (HP)	1.000				
(2) B/S ratio	0.207*	1.000			
(3) Main bearings	0.223*	-0.058*	1.000		
(4) Tire size (cm)	-0.025*	0.074*	-0.289*	1.000	
(5) Number of passengers	0.270*	-0.024	0.032*	0.043*	1.000

Table 9. Result of hedonic analysis in automobile industry

	Coefficient	Std. Err.
(1) log Horsepower (HP)	0.292***	(0.012)
(2) log B/S ratio	0.199***	(0.011)
(3) log main bearings	2.488***	(0.081)
(4) log Tire size (cm)	0.123***	(0.014)
(5) log No. of passengers	1.029***	(0.020)
Constant	0.210	(0.260)
Year Dummy	(Included)	
Firm Dummy	(Included)	
No. of Observations	13962	
Adjusted R^2	0.9061	

Notes: The values in parentheses are standard errors; *, ** and *** indicate statistical significance at the 10, 5 and 1% levels, respectively.

The variables finally used in the survival analysis are presented in Table 10. They consist of a size of firm and early entry-related variables derived via previous studies, and adaptation strategy variables such as technology level, technology increase rate, product dispersion, and product differentiation variables. The adaptation strategy variables were derived by converting product-level data into firm-level variables using the previously mentioned method. Table 11 shows the basic statistics about variables to be used in the analysis and Table 12 shows comparison of firm strategic variables by firm characteristics, while Table 13 presents their correlations.

Figure 5 shows yearly product distribution on the basis of technology level of products indexed through the hedonic analysis. This graph shows a frequency distribution table of corresponding characteristics over time. It is a plan view of a three-dimensional graph (time, frequency, and characteristic value). A high peak means that new products with a corresponding technology level or characteristic are dense. As the graph shows, products are evolved while it forms a mountain-like shape. The ridge of the mountain-like shape is a technological trajectory. Such a trajectory corresponds to the dominant design. In the case of the automobile industry, peaks and ridges are formed gradually, and the highest peak is formed between 1912 and 1913. The technological characteristic of the Ford Model T is located in this peak. Additionally, Figure 6 and Figure 7 show the yearly frequency distribution of product with respect to engine volume and wheel base, respectively. During the shakeout period, product density is gradually decreasing, and then the additional product line is formed only after the shakeout period.

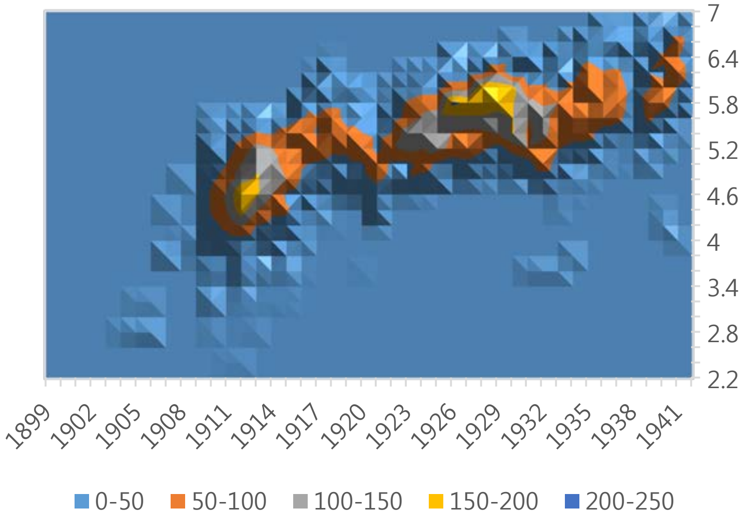


Figure 5. The distribution of variable related to level of technological competence in automobile industry

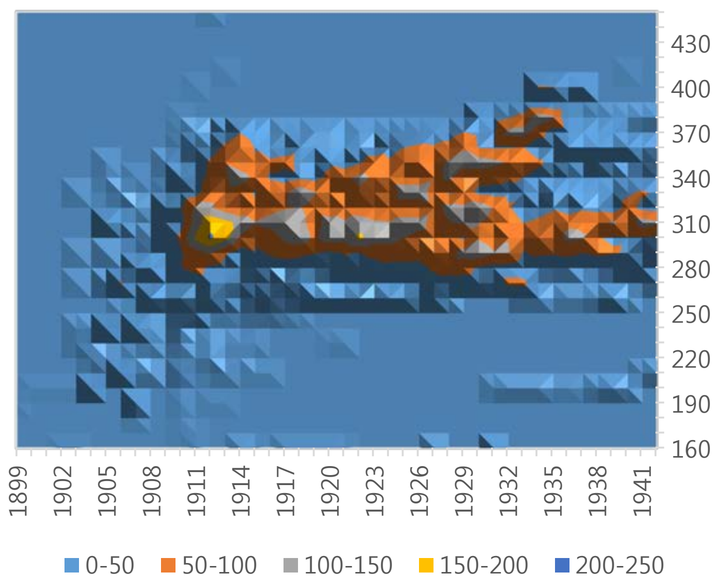


Figure 6. The distribution of level of Wheelbase in automobile industry

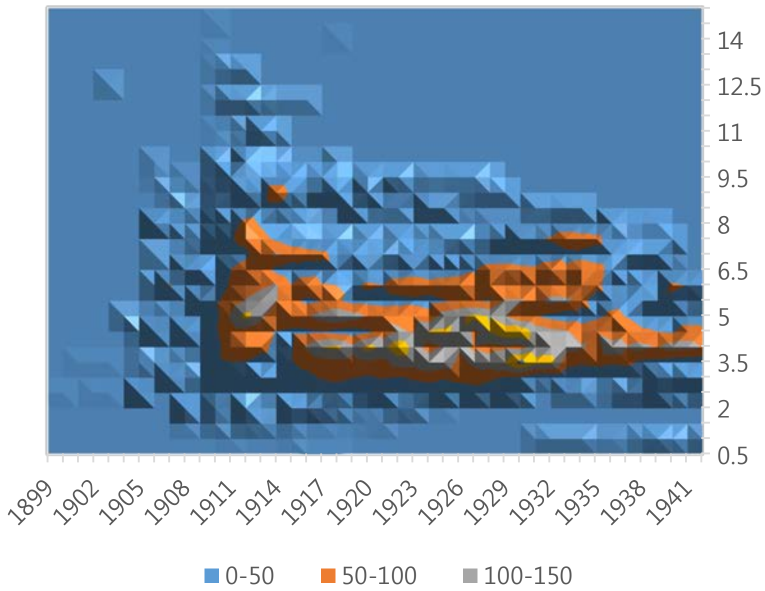


Figure 7. The distribution of level of displacement in automobile industry

Table 10. Summary of independents variables in survival analysis of automobile firm

Variables	Summary
$First\_mover\_dummy$	Enter during stage I, then first mover dummy equal 1.
$Size\_dummy$	Market share top 10.
$Technology\_level$	Level of firm's technology.
$Technology\_growth$	Increase rate of firm's technology level.
$Product\_dispersion$	Dispersion ratio of firm's products
$Product\_difference$	About differencing of firm's products

Table 11. Descriptive statistics of firm strategic variables in automobile industry

Variable	Obs.	Mean	Std. Dev.	Min	Max
$First\_mover\_dummy$	2109	0.234	0.424	0	1
$Size\_dummy$	2109	0.111	0.314	0	1
$Technology\_level$	2109	0.960	0.019	0.859	1
$Technology\_growth$	2109	0.455	1.103	-7.567	4.379
$Product\_dispersion$	2109	0.125	0.228	0.000	2.026
$Product\_difference$	2107	0.456	0.218	0.098	2.524

Table 12. The comparison of firm strategic variables by firm characteristics in automobile industry

Variable	Top 10	Non Top 10	Early Entry	Late Entry
$Technology\_level$	0.961	0.966	0.968	0.961
	(0.019)	(0.020)	(0.020)	(0.019)
$Technology\_growth$	0.467	0.453	0.494	0.374
	(1.002)	(1.119)	(1.052)	(1.197)
$Product\_dispersion$	0.158	0.120	0.149	0.082
	(0.224)	(0.228)	(0.248)	(0.181)
$Product\_difference$	0.489	0.452	0.448	0.47
	(0.183)	(0.222)	(0.216)	(0.222)

Notes: The values in parentheses are standard errors.

Table 13. Correlation table of firm strategic variables in automobile industry

	(1)	(2)	(3)	(4)	(5)	(6)
(1) $First\_mover\_dummy$	1.000					
(2) $Size\_dummy$	0.140*	1.000				
(3) $Technology\_level$	0.132*	-0.126*	1.000			
(4) $Technology\_growth$	0.019	0.005	0.113*	1.000		
(5) $Product\_dispersion$	0.147*	0.052*	0.015	0.114*	1.000	
(6) $Product\_difference$	0.095*	0.053*	-0.286*	-0.134*	0.000	1.000

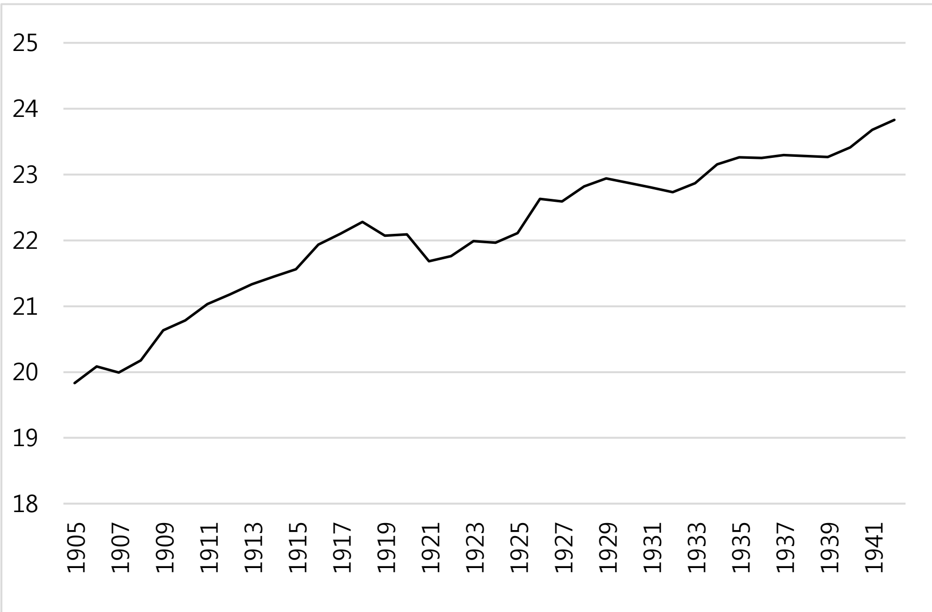


Figure 8. The change of level of overall technological competence by the year in automobile industry

Figure 8 shows the yearly technology levels measured by industry level among the derived variables in the above. Technology increase was in decline temporarily at the shakeout period; however, in general, of the trend was upward sloping.

To interpret the basic statistics with regard to adaptation strategies of survived and kicked-out firms, box plots of adaptation strategy distribution of each firm type by time are presented in Figure 9 to Figure 12. In the case of technology level, a difference of adaptation strategies between survived and kicked-out firms was not found over the whole period. However, in the case of the technology increase rate, there was a difference of distribution prior to the shakeout period, and technology increase rate of survived firms was higher than that of kicked-out firms. With respect to product dispersion, no difference of strategy distribution was found. On the other hand, with respect to technology differentiation, kicked-out firms took differentiated product strategy prior to the shakeout, while survived firms adopted differentiated strategy during the shakeout and kicked-out firms did so after the shakeout.

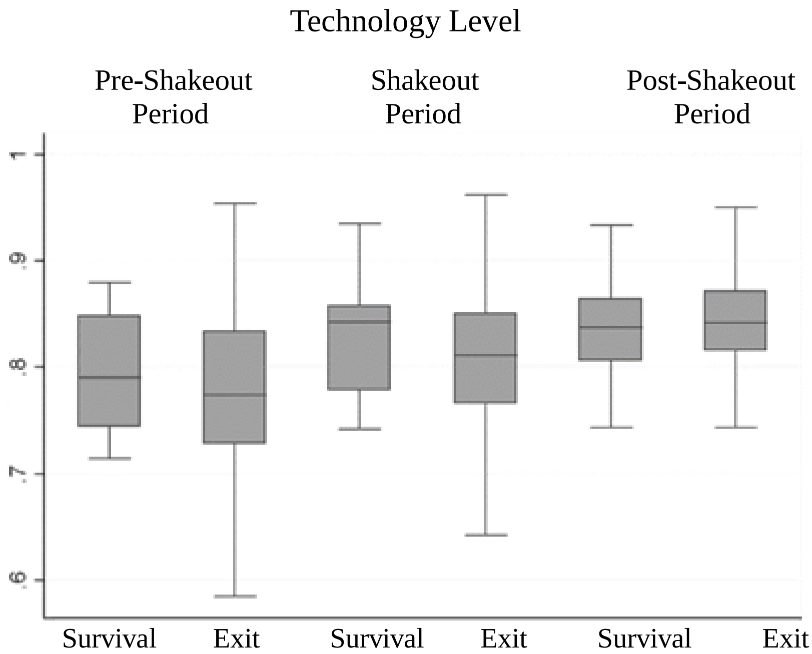


Figure 9. The comparison of technology level of survival and non-survival firms by shake out period classification

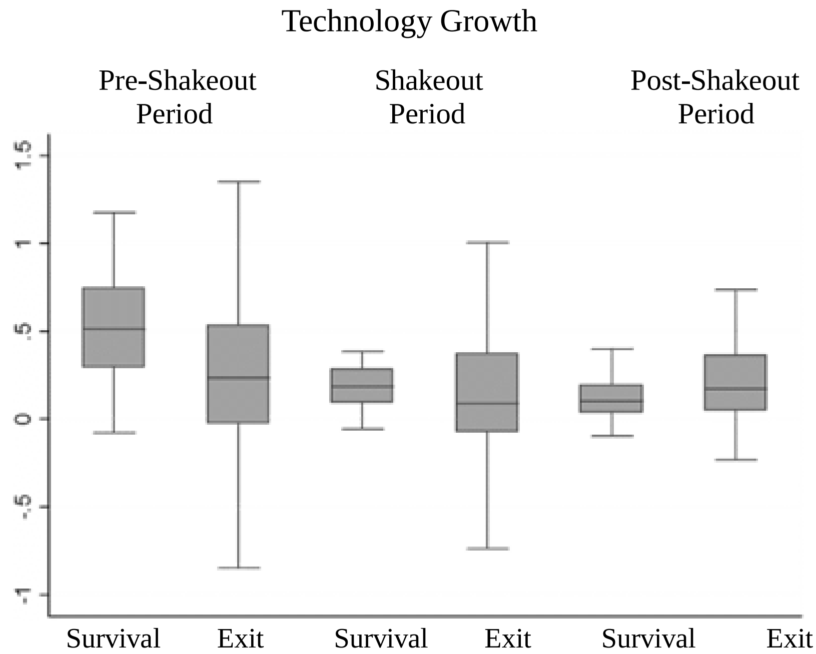


Figure 10. The comparison of technology growth of survival and non-survival firms by shake out period classification

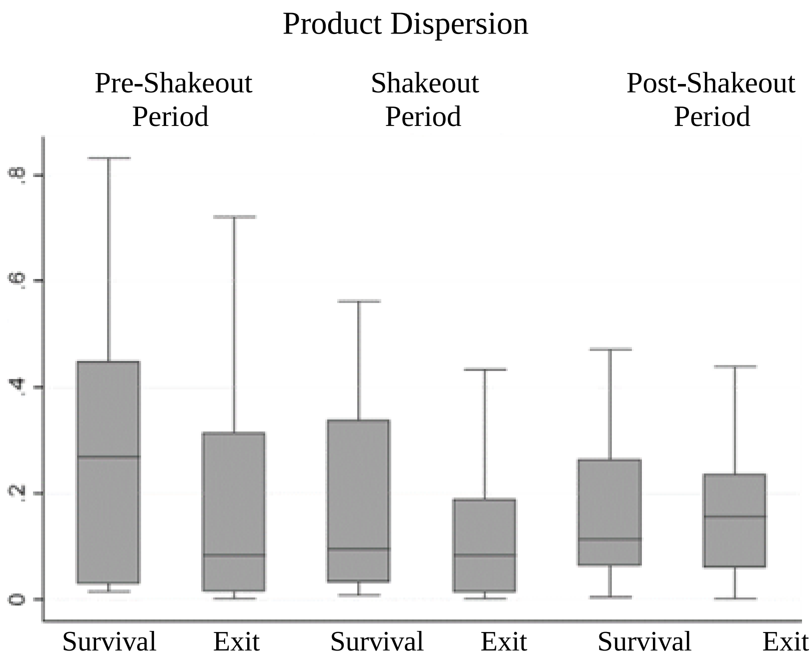


Figure 11. The comparison of product dispersion of survival and non-survival firms by shake out period classification

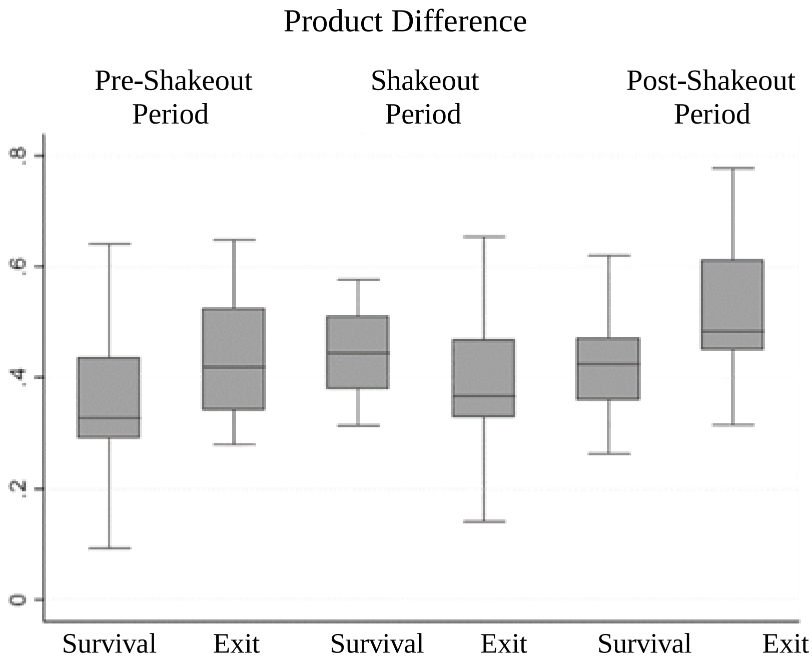


Figure 12. The comparison of product difference of survival and non-survival firms by shake out period classification

4.4.3 Survival analysis result

In this subsection, empirical analysis results of the Cox proportional hazards model are presented and explained to derive and discuss adaptation strategies and selection mechanism in the automobile industry centered on the shakeout period. The analysis in the automobile industry consists of three models. The first analysis is a basic model, in which the effects of size and entry timing of firms derived through previous studies and technology level, technology increase rate, product dispersion, and product differentiation suggested as adaptation strategies of firms on survival of firms are determined. The regression result is presented in Table 14. Depending on the shakeout time division, results can be different; thus, we had different time divisions (one and two years before and after the selected period). The empirical results for these divisions are presented in the Appendix; these are not significantly different from the regression results contained in this paper. Thus, we believe our result is robust.

Next, to determine whether a difference of adaptation strategy and selection mechanism (that is control effect) is present depending on firm size and entry timing derived via previous studies, regression results of the Cox proportional hazards model, in which dummy variables are used as interaction terms, are shown in Table 15 and Table 16, respectively.

All analyses were done by dividing the data into prior to shakeout, during shakeout, and after shakeout. In addition, dependent variables represent a hazard ratio, in which a negative correlation means a positive effect on survival, while a positive correlation means a negative effect on survival.

Table 14. The result of survival analysis of firm in automobile industry

	Pre-Shakeout	Shakeout	Post-Shakeout
$Size\_dummy$	-40.081***	-36.327***	-35.765***
	(0.446)	(0.411)	(0.491)
$First\_mover\_dummy$	-0.894***	-0.828***	-0.936*
	(0.208)	(0.264)	(0.539)
$Technology\_level$	0.295	0.204	1.389
	(0.795)	(0.833)	(1.240)
$Technology\_growth$	-0.016*	0.008	-0.017
	(0.008)	(0.009)	(0.021)
$Product\_dispersion$	-0.076	0.043	-0.102
	(0.072)	(0.061)	(0.114)
$Product\_difference$	0.111*	-1.098**	0.801**
	(0.059)	(0.503)	(0.383)
Log Likelihood	-393.3	-232.3	-83.48
Observation	233	1458	418

Notes: The values in parentheses are standard errors; *, ** and *** indicate statistical significance at the 10, 5 and 1% levels, respectively.

The regression result in the basic model showed that a size dummy and an early entry dummy had a negative correlation over the entire range. That is, these results are consistent with the formalized facts derived through the previous studies. However, coefficients of product dispersion and technology level showed no significant result.

Next, the regression results with respect to adaptation strategies are as follow. First, a coefficient of a technology increase rate is -0.016 prior to the shakeout period, indicating that it was advantageous to survival. This is inconsistent with the hypothesis that since product quality does not satisfy consumer’s demand in the early stage of industry, technology advancement at a faster rate is needed (Agarwal & Bayus, 2002). However, the coefficient of product differentiation at this time was 0.111. This means that an imitation strategy is more effective than product differentiation. This is in opposition to the result concerning the hypothesis mentioned in the above. The meaning of this result can be interpreted as follows. Since the dominant design is not firmly established in the early stage of industry, firms need to see the direction or behavior of other firms and imitate the main released products. Conversely, the dominant design is not established at a particular point. Rather, it is a process of finding a consensus through continuous imitations of many firms.

In contrast, the result at the shakeout period showed that the coefficient of product differentiation was -1.098. That is, survival rate of firms that attempted differentiation was higher than that of firms without differentiation. This was also a different result from the hypothesis. Previously, since a shakeout is a time after the dominant design was established, it was expected that products that did not follow the dominant design, which implied a similar product, would be kicked out. However, survival rate of firms that attempted differentiation was, unexpectedly, higher. If the shakeout period is interpreted as a time that most firms are kicked out and swept away by a big wave, firms may believe that they needed to release different products than others in order not to be swept away.

It was found that, an imitation strategy is advantageous to survival of firm again after the shakeout period. Here, the coefficient of product differentiation was 0.801. That is, after an industry is stabilized, adaptation strategy through imitation again raised survival rate. This is interpreted as indicating that firms that manufacture products formalized in each segment would have an advantage, as the segment of a product that is pioneered through differentiation strategy in the shakeout period is firmly established.

In summary, prior to the shakeout period, firms need an adaptation strategy that imitates potential dominant design products as they pay attention to products of other firms, while during the shakeout period, most firms are kicked out, so they need an adaptation strategy of product differentiation from other firms to survive the cull.

Next, it will be discussed how these adaptation strategies and survival mechanisms are changed depending on the size of firms. The survival analysis result according to the size of firm is shown in Table 15, while the survival analysis result according to the entry timing is shown in Table 16.

The method of interpretation of interaction terms is as follows. An example of how to interpret the technology level variable that did not multiply the interaction term in Equation (4.4) and its coefficient value $\gamma_1 \times Technology\_level$, as well as the technology level variable that used a size dummy as interaction term and its coefficient value $\gamma_2 \times Technology\_level \times Size\_dummy$, is given here. γ_1 is a derived value regardless of size of firms. This is because all data in large-sized and small and medium-sized firms is used to estimate γ_1. However, in the case of γ_2, only when a size dummy is 1 is it included in the estimation equation. Therefore, γ_2 means a marginal effect or control effect of large sized firms. In this case, care will be taken not to interpret γ_1 as an effect of small and medium sized firms. Therefore, the reason for the estimation of models with interaction term is to determine whether the effect of adaptation strategies can differ depending on size or entry timing of firms. Table 15 presents the differentiated effect of variables that used interaction terms. The analysis result showed that variables that do not use interaction terms in each model did not show any contradictory result against the basic model presented in Table 14, while no strategies were changed by size of firm and entry timing of firms. Therefore, the same result as that shown in Table 14 was derived. However, a control effect of strategy variables was the same as shown in Table 17. That is, although adaptation strategies that were advantageous to survival differed according to time on the basis of shakeout, the adaptation strategies were not different by size or entry timing of firms. However, only marginal effect was different. These facts prove that results derived from Table 14 were stabilized results.

Table 15. The comparison of survival analyses by firm size in automobile industry

	Pre-Shakeout	Shakeout	Post-Shakeout
$Size\_dummy$	-36.442***	2.041**	-2.525**
	(0.796)	(0.956)	(1.244)
$First\_mover\_dummy$	-0.870***	-1.072***	-1.064**
	(0.199)	(0.295)	(0.496)
$Technology\_level$	0.160	0.193	1.622***
	(0.770)	(0.270)	(0.570)
$Size \times Technology\_level$	0.004	-0.031*	-0.055
	(0.006)	(0.018)	(0.036)
$Technology\_growth$	-0.014*	0.021**	-0.029
	(0.008)	(0.009)	(0.019)
$Size \times Technology\_level$	0.023	-0.016*	0.003
	(0.023)	(0.009)	(0.015)
$Product\_dispersion$	-0.090	-0.137	11.624***
	(0.070)	(0.132)	(3.222)
$Size \times Product\_dispersion$	0.061	0.124	-11.780***
	(0.119)	(0.133)	(3.217)
$Product\_difference$	0.101*	-0.797*	-1.061
	(0.060)	(0.458)	(0.715)
$Size \times Product\_difference$	-0.115	0.770*	1.428**
	(0.174)	(0.462)	(0.721)
Log likelihood	-418.7	-575.9	-46.01
Observation	233	1458	418

Notes: The values in parentheses are standard errors; *, ** and *** indicate statistical significance at the 10, 5 and 1% levels, respectively.

Table 16. The comparison of survival analyses by time of entry in automobile industry

	Pre-Shakeout	Shakeout	Post-Shakeout
$Size\_dummy$	-36.343***	-43.533***	-38.635***
	(0.433)	(0.432)	(0.513)
$First\_mover\_dummy$	-0.797	-1.023	-2.074***
	(0.619)	(0.684)	(0.693)
$Technology\_level$	-0.205	0.915	1.092
	(0.327)	(0.746)	(1.710)
$First \times Technology\_level$	0.022	0.064**	-0.143**
	(0.022)	(0.030)	(0.066)
$Technology\_growth$	-0.014*	-0.006	-0.037
	(0.008)	(0.011)	(0.023)
$First \times Technology\_level$	0.013*	0.024	-0.012
	(0.007)	(0.017)	(0.039)
$Product\_dispersion$	0.043	0.038*	0.209
	(0.081)	(0.023)	(0.152)
$First \times Product\_dispersion$	-0.098	0.009	-1.569**
	(0.165)	(0.105)	(0.680)
$Product\_difference$	0.006	0.114	0.702
	(0.156)	(0.226)	(0.559)
$First \times Product\_difference$	-0.274	-1.618*	5.582***
	(0.304)	(0.826)	(1.813)
Log Likelihood	-213.6	-211.0	-45.23
Observation	233	1458	418

Notes: The values in parentheses are standard errors; *, ** and *** indicate statistical significance at the 10, 5 and 1% levels, respectively.

Table 17. The moderating effect of firm characteristics on survival analysis in automobile industry

	Moderating effect of large firms			**Moderating effect of first mover firms**		
	Pre-Shakeout	Shakeout	Post-Shakeout	Pre-Shakeout	Shakeout	Post-Shakeout
$Technology\_level$	.	Effect increased	.	.	Effect decreased	Effect increased
$Technology\_growth$	.	Effect increased	.	Effect decreased	.	.
$Product\_dispersion$	.	.	Effect increased	.	.	Effect increased
$Product\_difference$	.	Effect decreased	Effect decreased	.	Effect increased	Effect decreased

4.5 Sub-conclusion

This chapter showed how adaptation strategies and selection mechanism were changed depending on the evolutionary process on the basis of shakeout using product data from the US automobile industry.

There are selection and adaptation laws in the survival law in evolutionary economics. However, few studies have been conducted on adaptation strategies. Thus, this study aimed to overcome this limitation using product level data to consider the adaptation strategies.

Survival analysis was conducted in consideration of technology level, technology increase rate, product dispersion, and product differentiation variables derived from data of product level and size and entry timing of firms studied mainly in previous studies. Three analysis results were derived using the Cox proportional hazards model: the first analysis used a basic model, the second analysis used a model in which a size dummy of firm was used as interaction term, and the final analysis used a model in which an entry timing dummy was used as interaction term. The main results are as follow.

Regardless of the evolutionary stages of industry, large size and early entry firms had high survival rates in all ranges, which is inconsistent with the formalized facts in previous studies. With respect to the adaptation strategies, different adaptation strategies were derived depending on time of the cycle. Prior to the shakeout, product differentiation strategies had a negative effect on survival probability. That is, an imitation strategy was advantageous to survival in this period. This result indicated that firms need to review products from other firms and require adaptation strategy that imitates potentially dominant design products prior to the shakeout. This result hinted at how the dominant design is formed such that the dominant design is not given from the outside but is formed via a kind of consensus through imitation by firms in the same industry.

In addition, this period showed that technology increase rate had a positive effect on survival. This is also interpreted as meaning that most products in the early stage may not satisfy the consumers' requirements so that it is necessary to heighten the technology increase rate.

It is also found that a product differentiation strategy during the shakeout period influences survival of firms positively. It was expected that since this stage is comes after establishment of the dominant design, it would be advantageous to imitate the dominant design products. However, our result showed the opposite to be the case. The reason for this outcome can be interpreted as indicating that a shakeout period is a time when most firms are kicked out, so that firms need product differentiation strategies that differ from those of other firms in order not to be swept away by the exit wave.

From the model that used interaction terms with size of firms, it was found that adaptation strategies taken by large and small-and-medium firms were different from each other, while there was no noticeable difference of adaptation strategy between early entry firms and other firms in the analysis that used interaction terms with entry timing.

As can be seen in this chapter, adaptation strategies and selection mechanisms only for the shakeout period are present. Interestingly, most firms are kicked out of the industry during the shakeout period, while only a few firms survive as they were selected by the market environment. Therefore, it is required to behave during the shakeout period contrary to common sense derived from previous studies. That is, kicking out most firms is the selection mechanism in a shakeout, while behaving in the opposite way to common sense is an adaptation strategy specialized for this period.

Chapter 5. Adaptation strategy and selection mechanism in the mobile industry

5.1 Empirical research of mobile industry

This chapter aims to determine whether there is a change in adaptation strategy and selection mechanism in firms during the shakeout period in comparison with the automobile industry discussed in the previous chapter and whether there exist a difference in commonly discovered adaptation strategies and selection mechanisms.

The US automobile industry in the previous chapter is classified as a traditional manufacturing industry, while the mobile industry is an Information and Communication Technology (ICT) device industry. The two industries differ in terms of industry characteristics. In addition, the automobile industry was created in the early 20th century, while the mobile industry was developed in the early 21st century. Therefore, due to the advanced economic and business theories, adaptation strategies that were effective in the past may not work today. For example, there would be no advantage to early entry firms in terms of knowledge preemption since imitation of knowledge has been quicker in recent industries than in the past (Nelson, 1995).

In addition, there is a difference in product characteristics. For example, the repurchase cycle of vehicles as durable goods is much longer than that of mobile products. There is also a difference of product life cycle between them. The product life cycle of mobile products has been shortening more and more, and is much shorter than that of vehicles (Bayus, 1998).

One other characteristic is that the automobile industry in the past was formed by the entrance of small size firms into the industry at the early stage (O'Hearn, 2007), while the current mobile industry has been formed by large-size firms who already produced other electronics products such as Samsung Electronics or LG Electronics.

Due to the above reasons, there would be a difference in adaptation strategies that are advantageous to survival of firms in the mobile industry in contrast with automobile industry, including selection mechanisms.

Therefore, in this chapter, a common survival law is derived through analysis of adaptation strategies and selection mechanisms in the mobile industry, and the effect of changes in environment by time or industry difference on adaptation strategies and selection mechanism is discussed.

5.2 Study design and hypothesis

5.2.1 Technological level of firms

As found in previous studies, there will be no difference in survival rates according to technology level of firms. In the automobile industry, the semi-medium-sized passenger car is the best-selling product rather than the highest technology product. On the other hand, in the mobile industry, the best-selling products are products with a relatively high technology level among product families, as shown by Samsung's Galaxy S series. Therefore, it is expected that a technology level of firms would be more influential on survival of firms in the mobile industry than the automobile industry.

Furthermore, as explained in the above, this study overcomes the ambiguity of assessment of technology level, as shown in previous studies on technology level, or innovation of firms, to assess a technology level in mobile analysis directly through product analysis.

5.2.2 Technology increase rate of firms

In the mobile industry, the Red Queen effect (Barnett & Hansen, 1996) can also occur. As explained before, this phenomenon refers to a situation in which, even if a firm has a high technological level but with low technological growth, that firm can be overtaken by competitors at any time. A product life cycle of the mobile industry is shorter than that of the automobile industry, and mobile technology has been advanced in a short time so that the effect of the technology increase rate in the mobile industry will play a more important role compared to the automobile industry.

It is expected that such an effect would be more important in the early stage of the industry than other stages. This is because products in the early stage are primitive in general, so the willingness to pay is low (Agarwal & Bayus, 2002). Therefore, if a firm has a fast technology increase rate to satisfy the consumer's requirement, that firm might by recognized as an innovative firm. That is, a technology level of a firm in the mobile industry would play a positive role in the survival of a firm, and this effect would be stronger than in the automobile industry. It is also expected that this effect would be more important in the early stage of the industry than in other stages.

5.2.3 Product dispersion of firm

This subsection aims to analyze how differences between generalist and specialist adaptation strategies are displayed according to the evolutionary stage of industry via the product dispersion strategy of firms. As explained previously, if we consider the introduction time of the dominant design in the evolutionary stage of industry, a dispersion strategy through a variety of product families would be effective prior to the introduction of the dominant design. That is, when various products are manufactured, a risk-diversification effect may be obtained, though capability cannot be focused and it is difficult to imprint specialized images of products on consumers' minds. Early entry firms at the early stage compete with one another to dominate product design. Therefore, a risk-diversification strategy that increases probability of a product to be included in the dominant design by releasing a variety of products will be effective at the early stage of industry evolution; however, after the dominant design appears, specialist firms that are focused on the dominant design will have an advantage.

However, the mobile industry, in contrast with the automobile industry, does not incur much cost to develop a product line; thus, most firms in the mobile industry are more likely to perform product dispersion than those in the automobile industry are. Therefore, it is rather expected that this effect would not exist in the mobile industry.

5.2.4 Product differentiation of firms

As discussed in the above, the product differentiation strategy of firms can be broadly divided into two: a strategy that targets a niche market, and a strategy that imitates the dominant design. It is expected that an imitation strategy would be advantageous in the shakeout period since the dominant design is already established. Therefore, it would be advantageous to imitate potential dominant design products in the early stage of industry by looking closely into a trend of products in other firms, since the dominant design is still being established in this period. However, it would be advantageous to develop unique images by attempting product differentiation at the later stage of industry evolution, which is stabilized.

Such an effect may be more evident in the mobile industry at the later stage of industry evolution depending on the firm size. It was viewed that once the dominant design is established, only the matured stage of industry evolution can bring the co-existence of small and large size firms in the same industry thanks to the capability of small size firms that take strategic niches (Caves & Porter, 1977; Newman, 1978). That is, according to the theory of strategic niche, a firm remains small but inhabits a niche that cannot be accessible by larger firms. In the mature stage in the cycle, disadvantages due to small size experienced by small companies can be overcome through the above strategy. Therefore, where firm size is small, a product differentiation strategy is expected to be advantageous to survival in the Phase III period.

5.3 Analysis model

5.3.1 Survival analysis

As in the analysis in the automobile industry, the Cox proportional hazards model was used to conduct survival analysis. The general equation in the Cox proportional hazards model is the same as explained above. However, there is a difference of variables used for survival analysis. As explained above, it is noticeable that firms with experience in electronic or computer industry enter in the mobile industry. Therefore, $De\ novo\_dummy$, a dummy variable of prior experience, was included in the analysis. If a firm had no experience in related industries and then entered into the mobile industry, it is assigned a value of 1, and if a firm had experiences in other related industries, it is assigned a value of 0. The Cox proportional hazards model used for the analysis is shown in Equation (5.1).

$$
\begin{aligned}
h(t) = h_0(t)\ \exp\{&\beta_1 \times Size\_dummy_i \\
&+ \beta_2 \times First\_mover\_dummy_i \\
&+ \beta_3 \times De\,novo\_dummy_i \\
&+ \beta_4 \times Technology\_level_{it} \\
&+ \beta_5 \times Technology\_growth_{it} \\
&+ \beta_6 \times Product\_dispersion_{it} \\
&+ \beta_7 \times Product\_difference_{it}\}
\end{aligned}
\tag{5.1}
$$

The hypothesis was that there would be a difference in adaptation strategy and selection mechanism according to a size, entry timing, and prior experience. Therefore, analysis was conducted by inserting adaptation strategy variables and other variables in the interaction terms. The reason for not using an analysis method by dividing analysis data was because this cannot identify a difference of groups with analysis on separated data. For example, if the direction of the coefficient value is different between large and small-and-medium size firms, its interpretation may be easy. However, if both of them had a positive correlation, then it cannot be claimed by comparison of coefficients that large size firms are more advantageous than small-and-medium size firms. Therefore, an analysis method that uses interaction terms was chosen. The Cox proportional hazards model based on size, entry timing, and prior experience are indicated in Equations (5.2), (5.3), and (5.4) respectively.

$$
\begin{aligned}
h(t) = h_0(t)\ \exp\{&\beta_1 \times Size\_dummy_i \\
&+ \beta_2 \times First\_mover\_dummy_i \\
&+ \beta_3 \times De\,novo\_dummy_i \\
&+ \beta_4 \times Technology\_level_{it} \\
&+ \beta_5 \times Technology\_level_{it} \times Size\_dummy_i \\
&+ \beta_6 \times Technology\_growth_{it} \\
&+ \beta_7 \times Technology\_growth_{it} \times Size\_dummy_i \\
&+ \beta_8 \times Product\_dispersion_{it} \\
&+ \beta_9 \times Product\_dispersion_{it} \times Size\_dummy_i \\
&+ \beta_{10} \times Product\_difference_{it} \\
&+ \beta_{11} \times Product\_difference_{it} \times Size\_dummy_i\}
\end{aligned} \tag{5.2}
$$

$$
\begin{aligned}
h(t) = h_0(t)\ \exp\{&\beta_1 \times Size\_dummy_i \\
&+ \beta_2 \times First\_mover\_dummy_i \\
&+ \beta_3 \times De\,novo\_dummy_i \\
&+ \beta_4 \times Technology\_level_{it} \\
&+ \beta_5 \times Technology\_level_{it} \times First\_mover\_dummy_i \\
&+ \beta_6 \times Technology\_growth_{it} \\
&+ \beta_7 \times Technology\_growth_{it} \times First\_mover\_dummy_i \\
&+ \beta_8 \times Product\_dispersion_{it} \\
&+ \beta_9 \times Product\_dispersion_{it} \times First\_mover\_dummy_i \\
&+ \beta_{10} \times Product\_difference_{it} \\
&+ \beta_{11} \times Product\_difference_{it} \times First\_mover\_dummy_i\}
\end{aligned} \tag{5.3}
$$

$$
\begin{aligned}
h(t) = h_0(t)\ \exp\{&\beta_1 \times Size\_dummy_i \\
&+ \beta_2 \times First\_mover\_dummy_i \\
&+ \beta_3 \times De\,novo\_dummy_i \\
&+ \beta_4 \times Technology\_level_{it} \\
&+ \beta_5 \times Technology\_level_{it} \times De\,novo\_dummy_i \\
&+ \beta_6 \times Technology\_growth_{it} \qquad (5.4) \\
&+ \beta_7 \times Technology\_growth_{it} \times De\,novo\_dummy_i \\
&+ \beta_8 \times Product\_dispersion_{it} \\
&+ \beta_9 \times Product\_dispersion_{it} \times De\,novo\_dummy_i \\
&+ \beta_{10} \times Product\_difference_{it} \\
&+ \beta_{11} \times Product\_difference_{it} \times De\,novo\_dummy_i\}
\end{aligned}
$$

5.3.2 Adaptation strategy variable

The identification of the adaptation strategy variables is the same as shown in Chapter 4. Since indexed values of product data through the hedonic price model are used similarly to in the automobile industry analysis, an identification process of adaptation strategy and equations can be applied as in the automobile industry analysis. That is, through the methods used in Chapter 4, variables of technology level, technology increase rate, product dispersion of firms, and product differentiation of firms can be derived.

5.4 Empirical analysis

5.4.1 Mobile industry

In 1947, the Bell Laboratory developed a cellular technology that can communicate continuously by connecting to nearby stations while moving. The first mobile phone was DynaTAC, developed by the Motorola in 1973. It was a prototype that was only successful in test communication, weighing 1.3kg. Subsequently, Motorola released the commercial mobile phone DynaTAC 8000x series in 1983. The price was $3,995, and it weighted 0.7kg. With 10 hours of charging time, this phone only allowed a half-hour phone call. Motorola released the StarTac 7760 series in 1998 through continuous development efforts. This was the first folder type mobile phone in the world, which sold more than 75 million phones. The market share of Motorola reached around 60% at that time. In 1998, Nokia (from Finland) overtook Motorola through the low-price phone sale strategy, targeting developing countries, and became the world's No. 1 company. Then, Nokia introduced a platform business model since 2000 that managed only high-value-added sectors, while the other sectors were outsourced. Nokia provided low- and medium-priced mobile phones that accounted for 60% of their total sales via a unified platform through the platform business model and can perform product development with use of standardized modules. That is, Nokia was able to gain the top market share with their strategy of volume sales of simple products with cheap price in the entry level market, just as Ford did in the US automobile industry. This strategy was highly successful and culminated in the Nokia 1100 released in 2003, which sold more than 200 million units around the world as a single model.

In the communication technology, there was also significant advancement. Originally, it was an analog method, which was called a first generation communication, and only a few firms existed in the market at this time. Since 1996, a mobile industry was established in earnest by the commercial second generation communication, which is distinguished from the first generation because of the transformation from analog to digital signals. In this period, there was a fierce competition in communication technology between the CDMA mode supported in the USA and Korea and the GSM mode supported in Europe. Then, the third generation communication with video phone capability was released onto the market. Even in this period, WCDMA as a successor to the GSM mode and CDMA2000 as a successor to the CDMA mode were in competition. From 2011 to now, the fourth generation, called LTE mode, which is five times faster than the third generation, has been commercialized.

5.4.2 Data and variables

5.4.2.1 Data

Data of the mobile industry can be obtained via information in a large number Internet web pages that review mobile products. Among them, GSM ARENA contains data of the most diverse range of products. Thus, we extracted data of mobile products from GSM ARENA using data mining. The extracted data includes data of all mobile products released around the world. We did not single out a country due to the characteristic of the mobile industry, selling products all around the world. A total of 5,508 products were found in the data and, among them, 3,416 feature phone products were targeted in the analysis. The reason for selecting only feature phones for the analysis is explained in detail below. The analysis period was set to 1994 to 2012. The reason for this is also explained later. In this analysis period, 94 firms and 26 sets of product performance-related data were included. A dummy variable for size of firm was used to have a value of 1 for the top 10 firms based on market share by sales volume. The use of dummy variables was to have consistency in the analysis, including interaction terms analyzed later. The prior experience of firms was verified via their web pages. Some firms, like Motorola, had no experience prior to entry, while some telecommunication firms, like Vodafone, even manufactured other mobile devices prior to entry. It was also found that firms with prior experience in electronic industries such as computer manufacturers were also actively entered to the mobile industry. Finally, some firms like Bosch entered from the machinery industry.

The mobile industry technology has advanced much in the short time since commercialized products were released in 1994. In particular, recently-released smartphones have been advanced to have similar functions as computers, such as document creation and editing as well as a panoply of application programs (Theoharidou, Mylonas, & Gritzalis, 2012). Figure 13 shows a yearly distribution of feature phone and smartphone manufacturing firms. Although the number of firms in the overall mobile industry seems to be increasing continuously in the figure, if the number of feature phone and smartphone manufacturing firms is compared closely, you will find that a shakeout occurred in the feature phone industry. Thus, it is necessary to decide whether feature phone and smartphone industries are different.

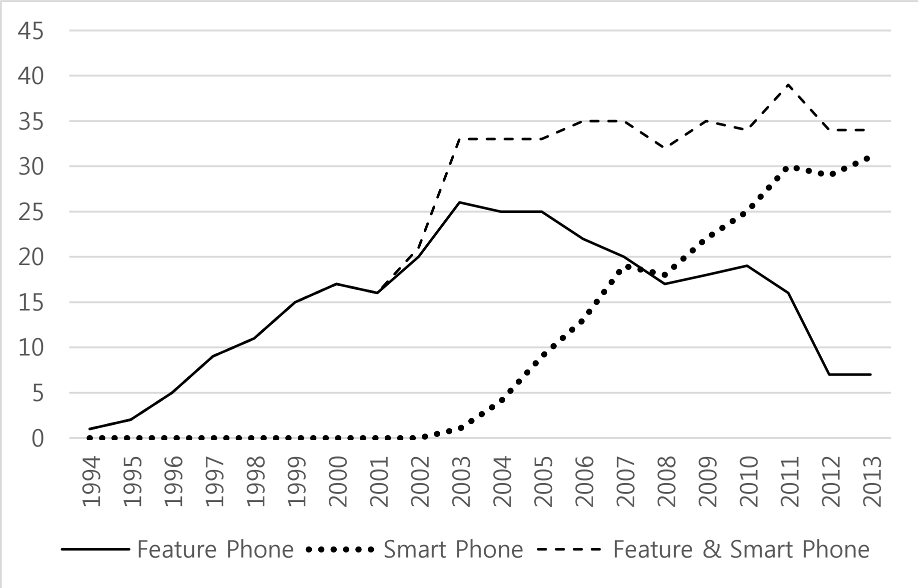


Figure 13. The change of the number of Feature phone-production firms and Smartphone-production firms

To answer this, it is necessary to review the definitions of the smartphone and feature phone. In general, existing mobile phones were called feature phones. However, the definition of smartphone has not yet reached a consensus; however, according to a study by Becher et al. (2011), a smartphone is defined as a mobile phone that contains a Mobile Network Operator Smartcard such as USIM or SIM and operating systems that can install third-party software. That is, the most important criteria that differentiate a feature phone and smartphone are the use of operating systems. In addition, the characteristic variables of products between feature phones and smartphones are considerably different so that they are needed to be classified into different product families.

Furthermore, there are also many differences between them over the industry characteristics. Nokia, which had been successful in the feature phone market in recent years, did not adapt well in the smartphone industry, and was consequently acquired by Microsoft. As such, industry and technological characteristics of the feature phone were different from those of the smartphone; thus, they were separated for the analysis. It is also true that a feature phone industry can be regarded as a new industry even if some firms manufacture smartphones and feature phones at the same time, since a large number of firms that only entered into the smartphone market are found.

Furthermore, there are many studies found that analyzed 5.25-inch and 3.5-inch hard disks differently in the case of the hard disk industry (Khessina & Carroll, 2008; Ruebeck, 2005). In this context, it is justified to analyze feature phones and smartphones separately.

Therefore, this paper conducted analysis on feature phones that experienced a shakeout. Figure 14 shows entries, exits, and the number of total firms in the mobile industry with regard to feature phones. In this figure, division by the industry life cycle was also marked. Although few firms entered during the shakeout period, some did. This fact proves that the entire industry is not in decline. In developed countries, the majority of people use smartphones, whereas feature phone market is still active in some countries. For example, the data indicated that firms in India and Eastern European countries are still entering into the feature phone market.

It is also found that the feature phone industry did not reach Phase III yet. Although Phase I and Phase II can be distinguished according to the classification of Dinlersoz and MacDonald (2009), there was no period when a net entry was converged to 0, as shown in Net Entry in Figure 15 for Phase III. However, the year of 2013 had net entry 0; thus, since then, it may have reached Phase III, which was why we excluded 2013 data from the analysis.

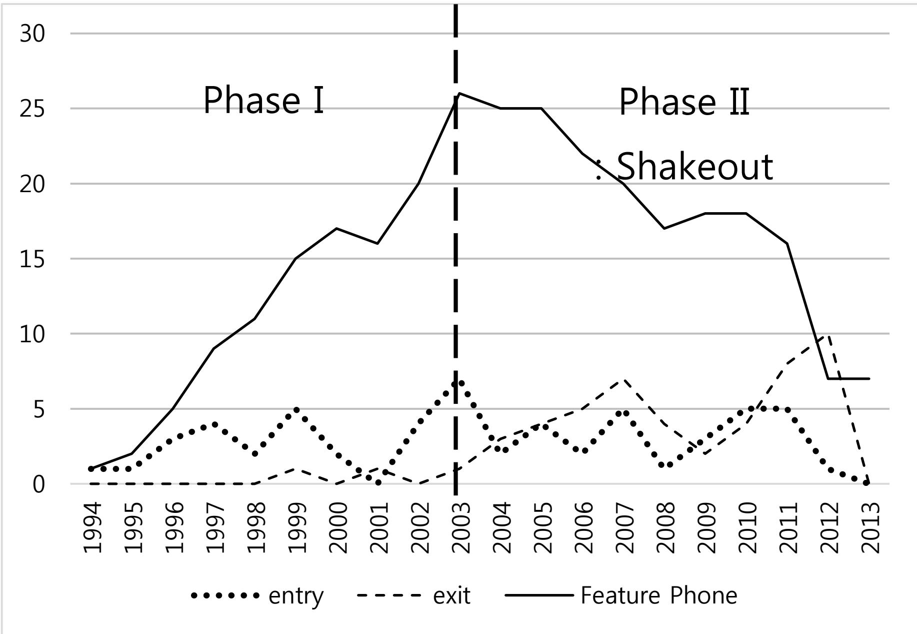


Figure 14. The number of exit and entrance firms in mobile-phone industry

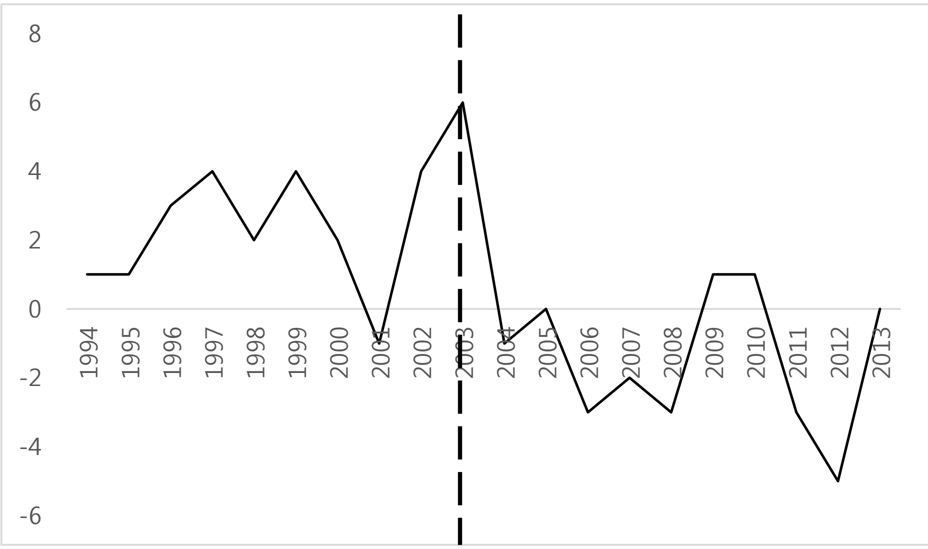


Figure 15. The change of net entry in mobile phone industry

5.4.2.2 Variables

Prior to identification of adaptation strategy variables, an indexation should be done first through the hedonic price model. The basic statistical data of variables used in the hedonic price model is shown in Table 18. As an index to represent mobile performance, volume of mobile device, color representation ability in screen, the number of sensors such as gravity or temperature sensors, battery performance via available standby time, and email usability were employed. As was the case in the automobile data, there were highly correlated variables found, in which case one or the other were chosen for use. For example, screen size or the number of pixels was highly correlated with size of mobile phone, so only volume of mobile phone was used as a variable. Correlations of the technological characteristic variables finally used are presented in Table 19.

In some feature phones, email can also be used. This feature phone was also included in the analysis since it was considered as a superior technology in terms of software compared to mobile phones that can send only text messages. The analysis results of the hedonic price model are shown in Table 20. R^2 that explained the analysis result was 0.7743.

Table 18. Descriptive statistics of variables related to technology and attributes of mobile

Variable	Obs.	Mean	Std.Dev.	Min	Max
(1) Dimension density	3416	88544	28392	21145	420736
(2) Display color depth	3416	865376	3338408	1	26000000
(3) Number of sensors	3416	0.142	0.470	0	5
(4) Battery standby time	3416	318.194	205.579	25	2400
(5) E-mail	3416	0.487	0.500	0	1

Table 19. Correlation table of variables related to technology and attributes of mobile

	(1)	(2)	(3)	(4)	(5)
(1) Dimension Density	1.000				
(2) Display color depth	-0.078*	1.000			
(3) Number of sensors	0.002	0.322*	1.000		
(4) Battery standby time	-0.100*	0.051*	0.083*	1.000	
(5) Email	0.032	0.201*	0.268*	0.126*	1.000

Table 20. Result of hedonic analysis in mobile industry

	Coefficient	Std. Err.
(1) log Dimension density	0.271***	0.069
(2) log Display color depth	0.079***	0.006
(3) log Number of sensors	0.335***	0.039
(4) log Battery standby time	0.150***	0.030
(5) Email dummy	0.368***	0.031
Constant	1.709*	0.894
Year Dummy	(Included)	
Firm Dummy	(Included)	
No. of Observations	3220	
Adjusted R^2	0.7679	

Notes: The values in parentheses are standard errors; *, ** and *** indicate statistical significance at the 10, 5 and 1% levels, respectively.

On the basis of technology level of indexed products through the hedonic analysis, yearly product distribution was presented. This graph is a frequency distribution table of corresponding characteristics over time. This is a plan view of a three-dimensional graph (time, frequency, and characteristics values). A high peak means that new products with corresponding technology level or characteristics are dense. As the graph shows, products are evolved while it forms a mountain-like shape, the ridge of which is a Technological Trajectory; the corresponding peak refers to the dominant design. Figure 16 is the distribution of variable related to level of technological competence in mobile phone industry. And Figure 17 shows a change in distribution over time according to mobile phone size. From the left side, distributions of overall mobiles, feature phones, and smartphones are shown.

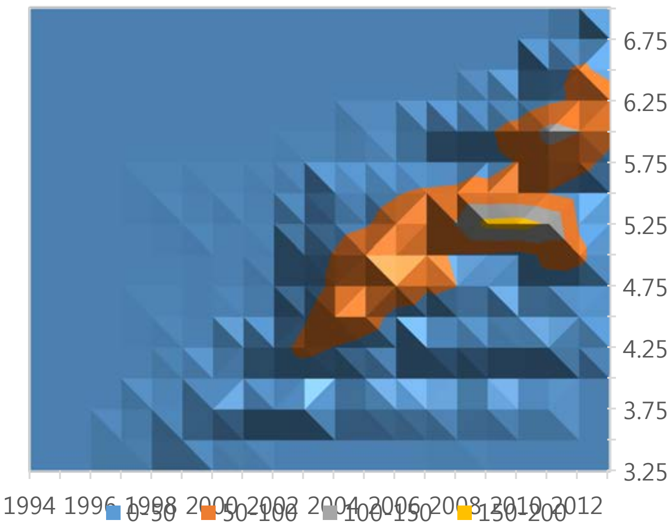


Figure 16. The distribution of variable related to level of technological competence in mobile phone industry

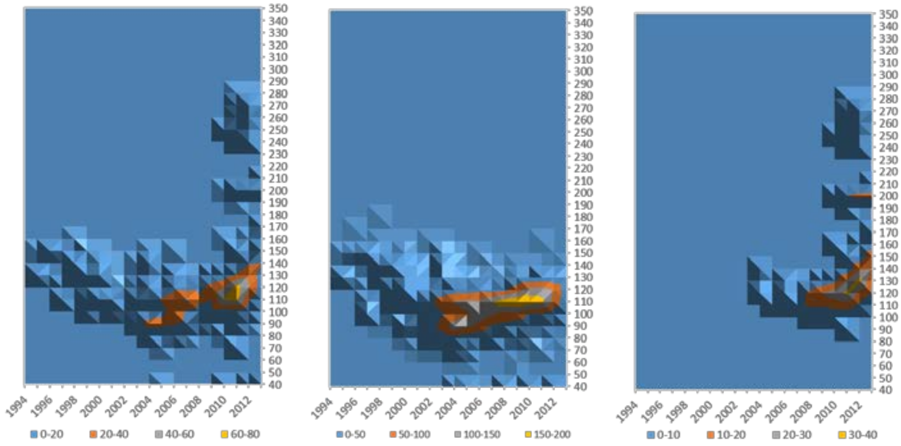


Figure 17. The distribution of level of size in mobile-phone industry

The variables finally used in the survival analysis are presented in Table 21. They consist of size of firm and early entry-related variables derived via previous studies including prior experience variables added by the mobile analysis, and adaptation strategy variables such as technology level, technology increase rate, product dispersion, and product differentiation variables. The adaptation strategy variables were derived by converting product-level data into firm-level variables using the previously mentioned method. Table 22 shows the basic statistics about variables to be used in the analysis and Table 23 presents the comparison of firm strategic variables by firm characteristics in mobile industry, while Table 24 presents their correlations. Figure 18 shows the yearly technology levels measured by industry level among the derived variables in the above. The technology increase grew continuously until decreasing slightly since 2011.

Table 21. Summary of independents variables in survival analysis of mobile firm

Variables	Summary
$First\_mover\_dummy$	Enter during stage I, then first mover dummy equal 1.
$Size\_dummy$	Market share top 10.
$De\ novo\_dummy$	Non pre-entry experience firms have value 1.
$Technology\_level$	Level of firm's technology.
$Technology\_growth$	Increase rate of firm's technology level.
$Product\_dispersion$	Dispersion ratio of firm's products
$Product\_difference$	About differencing of firm's products

Table 22. Descriptive statistics of firm strategic variables in automobile industry

Variable	Obs.	Mean	Std. Dev.	Min	Max
$Size\_dummy$	359	0.270	0.445	0	1
$First\_mover\_dummy$	359	0.722	0.449	0	1
$De\ novo\_dummy$	359	0.535	0.499	0	1
$Technology\_level$	359	0.895	0.058	0.695	1.000
$Technology\_growth$	359	1.590	4.934	-19.126	24.180
$Product\_dispersion$	359	0.459	0.681	1.428	5.897
$Product\_difference$	359	0.390	0.187	0.109	1.377

Table 23. The comparison of firm strategic variables by firm characteristics in mobile industry

Variable	Top 10	Non Top 10	Early Entry	Late Entry	*De novo*	*De alio*
$Technology\_level$	0.946	0.926	0.926	0.944	0.928	0.935
	(0.049)	(0.054)	(0.058)	(0.037)	(0.055)	(0.051)
$Technology\_growth$	1.382	1.670	1.748	0.975	1.38	1.791
	(4.372)	(5.131)	(4.923)	(4.760)	(4.520)	(5.276)
$Product\_dispersion$	0.736	0.357	0.531	0.277	0.516	0.394
	(0.798)	(0.603)	(0.677)	(0.662)	(0.683)	(0.675)
$Product\_difference$	0.386	0.392	0.403	0.359	0.394	0.386
	(0.176)	(0.191)	(0.202)	(0.141)	(0.171)	(0.205)

Notes: The values in parentheses are standard errors.

Table 24. Correlation table of firm strategic variables in mobile industry

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) $Size\_dummy$	1.000						
(2) $First\_mover\_dummy$	0.310*	1.000					
(3) $De\ novo\_dummy$	-0.169*	-0.017	1.000				
(4) $Technology\_level$	-0.042	-0.298*	-0.073	1.000			
(5) $Technology\_growth$	-0.028	0.066	-0.042	0.058	1.000		
(6) $Product\_dispersion$	0.248*	0.168*	0.089	-0.299*	0.021	1.000	
(7) $Product\_difference$	-0.014	0.107	0.020	-0.101	0.290*	0.234*	1.000

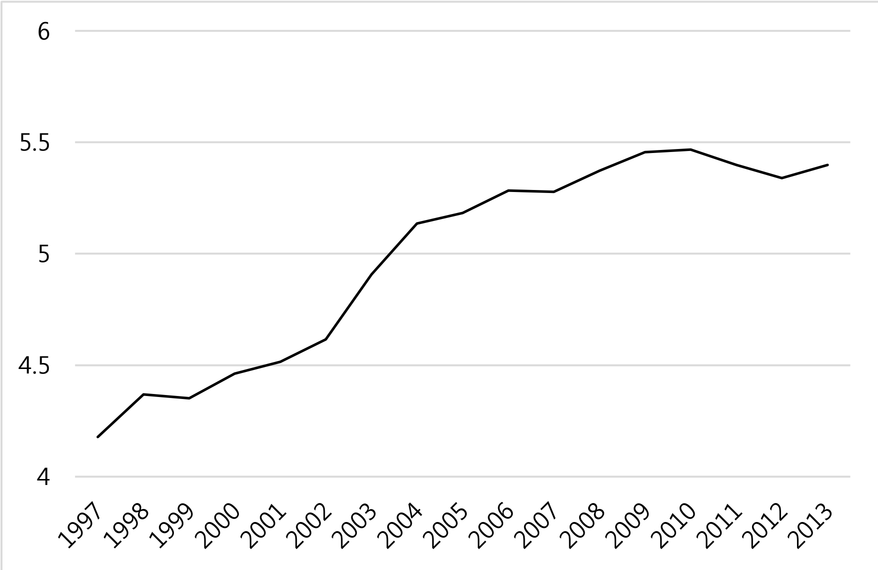


Figure 18. The change of level of overall technological competence by the year in mobile-phone industry

To interpret the basic statistics with regard to adaptation strategies of survived and kicked-out firms, box plots of adaptation strategy distribution of survived and kicked-out firms through time are presented in Figure 19 to Figure 22. In the case of the technology level, a difference of adaptation strategies between survived and kicked-out firms was revealed over the whole period. In addition, technology level was high in survived firms, so that technology level is expected to have a significant effect on survival of firms. However, in the case of the technology increase rate, there was a significant difference of distribution prior to the shakeout period, and technology increase rate of survived firms was higher than that of kicked-out firms. With respect to product dispersion, survived firms showed higher values in the shakeout period. This result indicates that firms that selected a strategy aiming to distribute their products over a broader range survived. With respect to technology differentiation, survived firms took a differentiation strategy in the shakeout period, although no significant result was revealed prior to the shakeout. Such box plot results verified that it is not different from the survival analysis result.

Technology Level

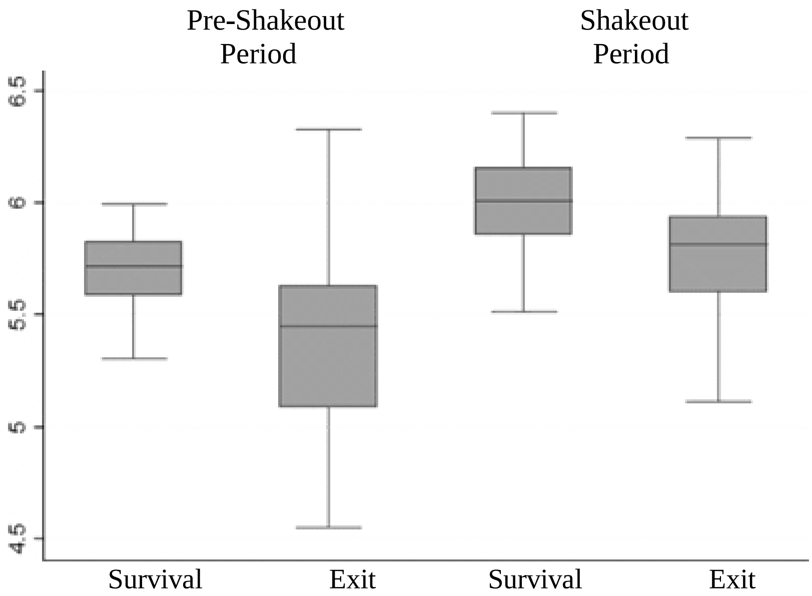


Figure 19. The comparison of technology level of survival and non-survival firms by shake out period classification

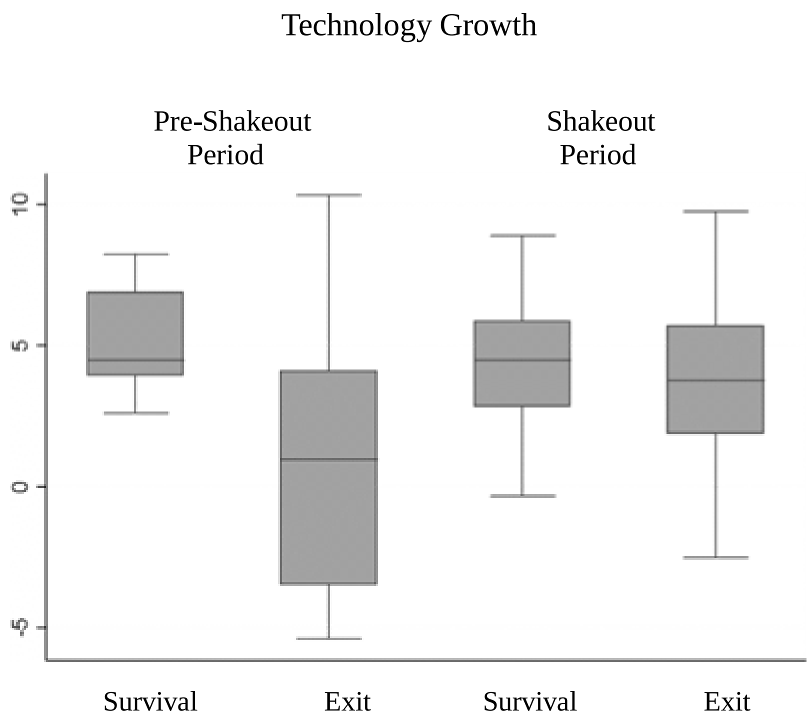


Figure 20. The comparison of technology growth of survival and non-survival firms by shake out period classification

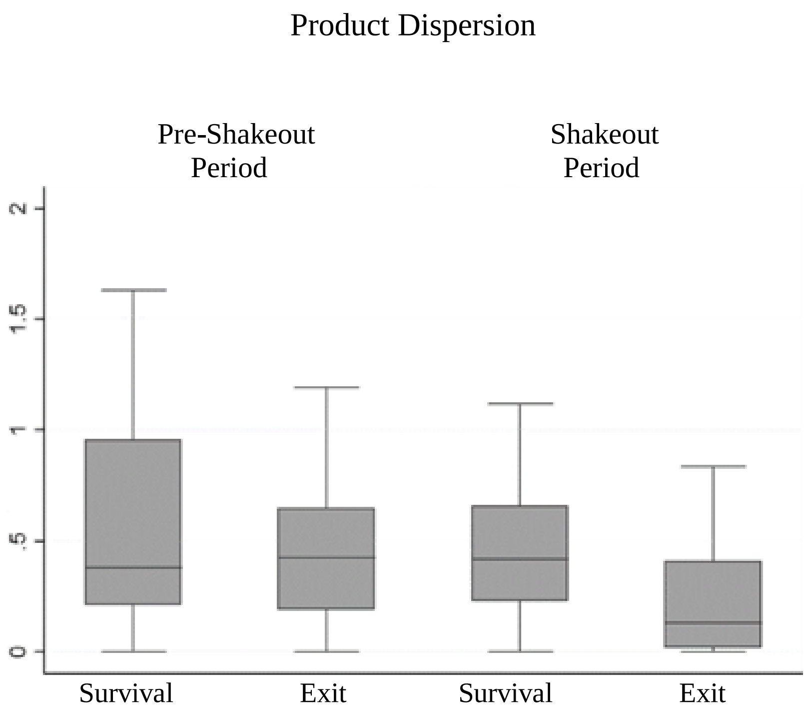


Figure 21. The comparison of level of product diversification of survival and non-survival firms by shake out period classification

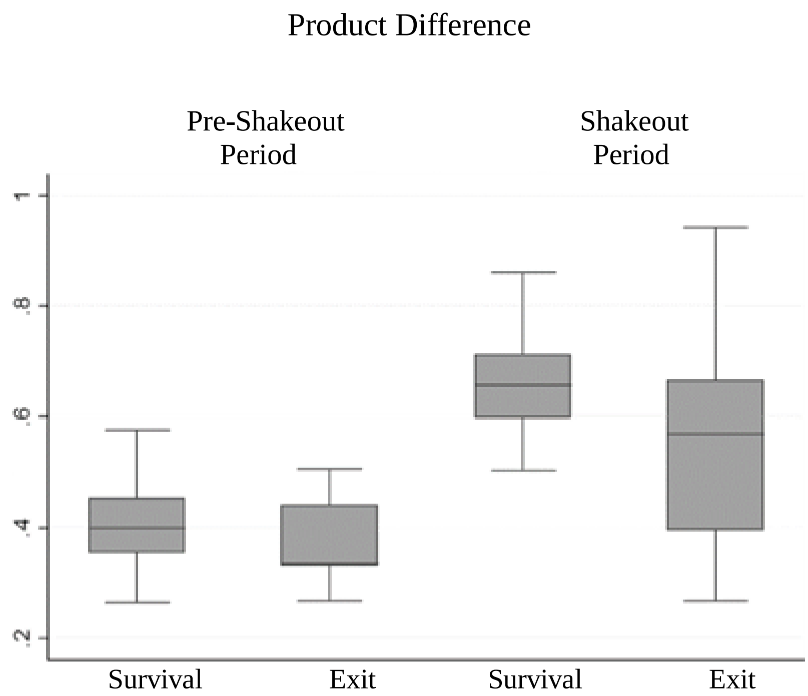


Figure 22. The comparison of differentiation level of survival and non-survival firms by shake out period classification

5.4.3 Survival analysis result

In this subsection, empirical analysis result of the Cox proportional hazards model is presented to derive adaptation strategies and selection mechanisms in the mobile industry centered on the shakeout period, and the results analysis is explained. The analysis in the mobile industry consists of four models. The first analysis is a basic model, in which the effects of size and entry timing of firms derived through previous studies and technology level, technology increase rate, product dispersion, and product differentiation suggested as adaptation strategies of firms on survival of firms are determined. The regression result is presented in Table 25. Results can vary depending on the shakeout time division, so we had different time divisions (one and two years before and after the selected period). The empirical results of these periods that are not significantly different from the regress result contained in this paper are presented in the Appendix. Thus, we believe our result is robust.

The second to fourth analyses are analysis results that used dummy variables as interaction terms in order to determine whether adaptation strategy and selection mechanism were different according to firm size, entry timing, and prior experience before the entry, which were derived through previous studies. The regression results of the Cox proportional hazards models for each of them are presented in Table 26, Table 27, and Table 28, respectively. However, in the case of the mobile industry, a shakeout is still occurring (or is just completed); thus, analysis was only conducted with regard to times prior to and during the shakeout period.

All analyses were done by dividing the data into prior to shakeout, during shakeout, and after shakeout. In addition, dependent variables represent a hazard ratio in which a negative correlation means a positive effect on survival while a positive correlation means a negative effect on survival. First, survival analysis results of the basic model are discussed below.

Table 25. The result of survival analysis of firm in mobile industry

	Pre-Shakeout	Shakeout
$De\ novo\_dummy$	-1.012	0.161
	(0.710)	(0.808)
$Size\_dummy$	-34.860***	0.295
	(2.347)	(0.933)
$First\_mover\_dummy$	0.960	2.050***
	(0.860)	(0.735)
$Technology\_level$	-5.389**	-7.535**
	(2.682)	(3.771)
$Technology\_growth$	-0.015*	-0.037
	(0.008)	(0.055)
$Product\_dispersion$	0.118	-1.100**
	(0.221)	(0.467)
$Product\_difference$	0.946	-2.702*
	(1.257)	(1.419)
Log Likelihood	-7.319	-18.05
Observations	117	242

Notes: The values in parentheses are standard errors; *, ** and *** indicate statistical significance at the 10, 5 and 1% levels, respectively.

All analyses were done by dividing the data into prior to shakeout, during shakeout, and after shakeout. In addition, dependent variables represent a hazard ratio in which a negative correlation means a positive effect on survival while a positive correlation means a negative effect on survival. First, survival analysis results of the basic model are discussed below.

Adaptation strategies and selection mechanisms prior to the shakeout period are discussed. It was found that the large-size firms dummy had a negative correlation. This result means that large size firms are advantageous to survival. In addition, the coefficient of technology level is -5.389. This means that firms with high technology level are advantageous to survival. The coefficient of technology increase rate was -0.015. That is, advantages of technology increase rate were discovered at the early stage of the industry. This period is a time in which consumers are not satisfied with the quality of product in terms of technology level. Accordingly, survival probability increases by increasing technology increase rate in order to meet the requirement of consumers in terms of technology level (Agarwal & Bayus, 2002).

At the time of shakeout, a coefficient of early entry firm dummy was 2.050, which showed a positive correlation. Accordingly, it was found rather that early entry firms were disadvantageous to survival. This result is different from that of previous studies. This result was obtained because the first mover advantage through information advantage, as in the early 1900s, cannot be enjoyed (Agarwal & Gort, 2001). However, the coefficient of technology level showed -7.535. This result means that firms with high technology have high survival probability. Furthermore, it was revealed that selling a variety of ranges in products was also advantageous to survival. In addition, the coefficient of product differentiation was -2.702. This means that a differentiation strategy increased survival probability of firms. In summary, concerning product dispersion and differentiation variables, product dispersion broadly by finding a niche area in the market will be a strategy that increases survival probability in the shakeout period. The *de novo* firm dummy had no significant value.

Next, it will be discussed how these adaptation strategies and survival mechanisms change depending on the size of firms, entry timing, and prior experiences. The survival analysis results according to the size of firm are shown in Table 26, while the survival analysis results according to the entry timing are shown in Table 27 and survival analysis results according to prior experience are shown in Table 28.

Table 26. The comparison of survival analyses by time of entry in mobile industry

	Pre-Shakeout	Shakeout
$De\ novo\_dummy$	-0.694	1.524*
	(0.644)	(0.856)
$Size\_dummy$	-2.484*	-1.149
	(1.444)	(2.827)
$First\_mover\_dummy$	1.063**	4.114**
	(0.498)	(1.605)
$Technology\_level$	-1.156*	-8.983***
	(0.594)	(3.168)
$Size \times Technology\_level$	-0.068**	-0.882**
	(0.031)	(0.362)
$Technology\_growth$	-0.025***	-0.053***
	(0.007)	(0.018)
$Size \times Technology\_growth$	-0.004	-0.297***
	(0.009)	(0.075)
$Product\_dispersion$	-0.134	-5.727***
	(0.102)	(1.993)
$Size \times Product\_dispersion$	0.145	5.026***
	(0.113)	(1.550)
$Product\_difference$	-0.717**	-4.774***
	(0.297)	(1.276)
$Size \times Product\_difference$	0.927**	6.878
	(0.393)	(6.154)
Log Likelihood	-24.03	-15.01
Observations	117	242

Notes: The values in parentheses are standard errors; *, ** and *** indicate statistical significance at the 10, 5 and 1% levels, respectively.

Table 27. The comparison of survival analyses by time of entry to the market in mobile industry

	Pre-Shakeout	Shakeout
$De\ novo\_dummy$	0.134	-0.234
	(0.845)	(0.716)
$Size\_dummy$	-0.274	-0.370
	(1.180)	(1.251)
$First\_mover\_dummy$	109.517***	6.770***
	(41.545)	(2.461)
$Technology\_level$	-9.774**	-8.454***
	(3.970)	(2.594)
$First \times Technology\_level$	-1.910***	-0.469**
	(0.680)	(0.217)
$Technology\_growth$	-0.121*	-0.029**
	(0.062)	(0.014)
$First \times Technology\_growth$	0.110*	-0.087*
	(0.060)	(0.046)
$Product\_dispersion$	1.308***	-47.421**
	(0.507)	(21.019)
$First \times Product\_dispersion$	-1.374***	46.021**
	(0.525)	(20.561)
$Product\_difference$	-8.426***	-4.655***
	(2.550)	(1.359)
$First \times Product\_difference$	7.912***	-0.154
	(2.370)	(1.764)
Log Likelihood	-19.78	-15.52
Observations	117	242

Notes: The values in parentheses are standard errors; *, ** and *** indicate statistical significance at the 10, 5 and 1% levels, respectively.

Table 28. The comparison of survival analyses by time of entry to the market in mobile industry

	Pre-Shakeout	Shakeout
$De\ novo\_dummy$	9.256**	-0.076
	(3.879)	(3.453)
$Size\_dummy$	-0.745	-1.750*
	(1.245)	(1.018)
$First\_mover\_dummy$	0.264	2.619***
	(0.510)	(0.929)
$Technology\_level$	0.031	-3.827
	(0.696)	(3.226)
$De\ novo \times Technology\_level$	-0.183**	-0.939**
	(0.072)	(0.454)
$Technology\_growth$	0.007	-0.062***
	(0.006)	(0.023)
$De\ novo \times Technology\_growth$	-0.027**	0.023
	(0.011)	(0.023)
$Product\_dispersion$	-0.242*	0.918
	(0.125)	(1.512)
$De\ novo \times Product\_dispersion$	-0.484	-3.707***
	(0.415)	(1.409)
$Product\_difference$	-0.933***	-15.412**
	(0.316)	(7.486)
$De\ novo \times Product\_difference$	0.420	12.698*
	(0.397)	(6.539)
Log Likelihood	-21.08	-16.97
Observations	117	242

Notes: The values in parentheses are standard errors; *, ** and *** indicate statistical significance at the 10, 5 and 1% levels, respectively.

Table 29. The moderating effect of firm characteristics on survival analysis in mobile industry

	Moderating effect of large firms		**Moderating effect of early entry**		**Moderating effect of *De novo***	
	Pre-Shakeout	Shakeout	Pre-Shakeout	Shakeout	Pre-Shakeout	Shakeout
$Technology\_level$	Effect increased	Effect increased	Effect increased	Effect increased	Effect increased	Effect increased
$Technology\_growth$	.	Effect increased	Effect decreased	Effect increased	Effect increased	.
$Product\_dispersion$	.	Effect decreased	Effect increased	Effect decreased	.	Effect increased
$Product\_difference$	Effect decreased	.	Effect decreased	.	.	Effect decreased

The method of interpretation of interaction terms is as follows: An example of how to interpret the technology level variable that did not multiply interaction term in Equation (4.5) and its coefficient value, $\gamma_1 \times Technology\_level$, as well as technology level variable that used a size dummy as interaction term and its coefficient value, $\gamma_2 \times Technology\_level \times Size\_dummy$, is given here. γ_1 is a derived value regardless of size of firms. This is because all data in large-sized and small and medium-sized firms are used to estimate γ_1. However, in the case of γ_2, only when a size dummy is 1 is it included in the estimation equation. Therefore, γ_2 refers to a marginal effect of a large-size firm. In this case, care should be taken not to interpret γ_1 as an effect of small and medium sized firms. Therefore, the reason for the estimation of models with the interaction term is to determine whether the effect of adaptation strategies can differ depending on size or entry timing of firms.

Table 29 presents the differentiated effect of variables that used interaction terms. The analysis results showed that variables that do not use interaction terms in each model did not show any contradictory result against the basic model presented in Table 25, while no strategies were changed by size of firm or entry timing of firm. Therefore, the same result was derived with that shown in Table 25. However, a differentiated marginal effect of strategy variables is the same as shown in Table 29. That is, although adaptation strategies that are advantageous to survival are differ by time on the basis of shakeout, the adaptation strategies are not different by size or entry timing. Only marginal effect was different. This fact proves that the derived result from Table 25 is a stable result.

5.5 Sub-conclusion

To identify adaptation strategies and selection mechanism according to stages in industry evolution, particularly at the time of shakeout, empirical analysis was conducted with respect to the mobile industry. Using the product data in the mobile industry, adaptation strategy variables such as technology level, technology increase rate, product dispersion, and product differentiation of firms were derived. In addition, major selection factors such as a size of firm, entry timing of firm, and prior experience of firm were derived through the identification of formalized facts from previous studies.

Furthermore, survival analysis was conducted as per stage of industry evolution using three variables derived from previous studies and four adaptation strategy variables via product analysis. Additionally, analysis that uses each dummy variable as interaction terms was also conducted to determine whether such an adaptation strategy is different or their effect is different depending on a size of firm, entry timing of firm, and prior experience of firm.

Note that since the characteristics of feature phone and smartphone are different from each other, this study only targeted feature phones for analysis. In addition, since characteristics of a time after shakeout in the mobile industry cannot be found, only periods of shakeout and prior to shakeout are analyzed. The main results were as follows.

The analysis result of the basic model showed that only size of firm was advantageous to survival at a time prior to shakeout, while the other two variables (entry timing and prior experiences of firm) did not have significant results. Such a result is in consistent with a claim by Agarwal & Gort (2001) and Nelson (1995) saying that recent industry cannot enjoy information advantage, thereby negating the effect. On the other hand, in the case of the mobile industry, there are companies that provide core technologies in mobile devices. For example, 90% of CDMA products use chips from Qualcomm. It was also shown that most parts in mobile devices are not developed by the firms but are purchased from other firms. Therefore, latecomers in the mobile industry had no advantage that early entry firms normally have because there is an environment that can adopt core technologies through the purchase of a number of parts, including chips, that already existed in the industry, and there is an effect of specialization of part adoption. In addition, the barrier to entry became lower for computer or notebook industries as well because there are firms that are specialized in manufacturing core parts, such as CPUs, memory, and hard disks, and firms can easily purchase them. Due to such effect, it is expected that the electronics industry may have no advantage for early entry firms in most cases.

Nonetheless, regardless of industry development stages, survival probability of firms increased in all stages if technology level was high. This is because the mobile industry is technology-oriented. In addition, prior to shakeout, if a technology increase rate was high, it was conducive to survival of firms. This conclusion was the same as in the automobile industry, in which no product could meet the consumers' requirements prior to shakeout (Agarwal & Bayus, 2002), thereby requiring a fast catch-up.

During the shakeout period, adaptation strategies that affect survival positively are high technology level, product dispersion, and product differentiation strategy. That is, this result means that survival of generalist firms is high in this period. This characteristic is only shown in the mobile industry (not the automobile industry). In the automobile industry, considerable

R&D cost is needed to release a variety of products, whereas the mobile industry requires relatively low costs for product dispersion.

With respect to the product differentiation strategy, the automobile industry had the same result. For the same reason, because this period is a time that selection mechanism is working, by which many firms are kicked out, firms should pursue differentiation through the product differentiation strategy to become one of the few survivors. As an alternative explanation, economies of scale should be established to compete with other firms through price competition in order to survive in the industry by following firms that developed the dominant design; thus, firms that are not able to achieve economy of scale should pursue the differentiation strategy to survive.

Chapter 6. Conclusion

6.1 Summary of this study

6.1.1 Adaptation strategy and selection mechanism at the shakeout period

In this study, formalized facts were derived by summarizing previous study results related to survival of firms at the shakeout period over the industry life cycle. Through the previous study results, it was found that size of firm, entry timing of firm to the industry, prior experiences of related industry by firms, and innovation of firms were main study areas.

With respect to a size of firm, the following formalized fact was derived from most study results: large-size firms that achieved economy of scale had survival advantages. On the other hand, other study results claimed that disadvantages due to size will disappear through the pioneer of niche markets after an industry is stabilized.

With respect to entry timing to industry, most studies discussed whether the first mover advantage was present or not. The majority of early study results acknowledged that early entry firms had advantages over latecomers, but since then some studies claimed that this is not so in some cases. In particular, many studies reported their results depending on occurrence time of the dominant design, where early entry firms had an advantage initially before the dominant design was established, but latecomers had an advantage after the dominant design was established because knowledge available was not useful anymore. In addition, some studies claimed that the first mover advantage of knowledge disappeared in recent industries, so that no more advantage for early entry firms could be discovered.

In relation to prior experiences before the entry, most studies acknowledged that *de alio* firms introduced from other related industries had a survival advantage. However, some studies claimed that if *de novo* firms survive in the shakeout period because *de alio* firms had high opportunity cost due to their allowable investment on other industries, then the survival probability of *de novo* firms will increase.

In addition, with respect to innovation of firms, all studies concluded that innovative firms had a high survival probability.

The following conclusions were made accordingly. Most previous studies presented selection mechanisms according to a size of firms, entry timing of firms, and prior experiences of firms. However, such factors ae easily changed by firms. Although they can give some implications regarding selection mechanism of a market, no significant implications for firms are given.

It was also found that few studies on early stage of industry were conducted by dividing stages of industry evolution. As can be seen in the formalized fact explained in the above, there is a severe change in environment in early days of industry; thus, such studies are highly important.

Therefore, it is necessary to overcome the limitation of previous studies by taking the adaptation efforts of firms into consideration along with the three selection factors derived in the above while performing empirical analysis in this study. In addition, this study aimed to analyze selection mechanisms and adaptation strategies of firms that change with differentiating evolutionary stages of industry to consider industry dynamics.

6.1.2 Adaptation strategies and selection mechanism in the US automobile industry

This chapter showed how adaptation strategies and selection mechanism were changed depending on the evolutionary process on the basis of shakeout using the product data in the US automobile industry.

There are selection and adaptation laws in the survival law in evolutionary economics. Among them, few studies have been conducted on adaptation strategies. Thus, this study aimed to overcome this limitation using product level data to consider the adaptation strategies. The adaptation strategies derived from the product level data were divided into four variables: technology level, technology increase rate, product dispersion, and product differentiation. Selection factors derived from previous studies were also considered to conduct survival analysis. The model used in the analysis was the Cox proportional hazards model, and the main results are as follow.

It was revealed that a large-size firm dummy and early entry dummy increased survival probability in all stages. This result is consistent with the formalized fact derived in the previous chapter. In addition, it was found that technology increase rate increased survival probability prior to the shakeout period. This is because technology level of products did not satisfy the consumers' requirement; thus, fast technology improvement rate influenced survival positively.

In addition, a product differentiation strategy had a positive effect on survival only in the shakeout period, whereas it had a negative effect in other periods. Therefore, it can be concluded that product differentiation was the best strategy at the shakeout period, while product imitation strategy was the best adaptation strategy at other periods. The reason for the positive effect of the imitation strategy on survival of firms prior to the shakeout in relation to the dominant design can be interpreted as meaning that firms learn the consumers' response through products of other firms and need to manufacture better selling products. That is, it is interpreted that the dominant design can be established through firms' iterative imitation of one another. In other words, this result is interpreted as meaning that the dominant design was not given from the outside but is derived through coordination between firms and consumers.

On the other hand, it is highly interesting to see that product differentiation should be attempted at the shakeout period. If it is helpful to follow the dominant design for survival, firms should release similar products. However, our result showed the opposite. That is, if firms follow the already-established dominant design, they need to win the price competition if they want to survive. However, if they do not follow this strategy, they cannot escape from the price competition and are kicked out without economies of scale. If interpreted differently, a shakeout period is a time in which most industries experienced exits of firms, which is different from general selection mechanisms. Therefore, it can be interpreted that a unique product should be developed through product differentiation to secure survival during a shakeout period.

6.1.3 Adaptation strategy and selection mechanism in the mobile industry

As in the previous chapter, survival analysis was conducted using adaptation strategy variables and selection factor variables.

The analysis result of the basic model showed that only size of firm was advantageous to survival at the time prior to shakeout, while the other two variables (entry timing and prior experiences of firm) did not show significant results. This result is inconsistent with a claim by Agarwal & Gort (2001) and Nelson (1995) that recent industry cannot enjoy information advantage, thereby negating the effect.

Nonetheless, regardless of industry development stages, survival probability of firms increased in all stages if technology level was high. This is because the mobile industry is technology-oriented. In addition, prior to shakeout, if technology increase rate was high, it was conducive to survival of firms. This conclusion was the same as in the automobile industry, in which no product could meet the consumer’s requirement prior to shakeout, thereby requiring a fast catch-up.

During the shakeout period, adaptation strategies that affect survival positively are high technology level, product dispersion, and product differentiation strategy. That is, this result means that survival of generalist firms is high in this period. This characteristic is only shown in the mobile industry, whereas the automobile industry did not show this characteristic. In the automobile industry, considerable R&D cost is needed to release a variety of products, whereas the mobile industry requires relatively little cost for product dispersion.

With respect to the product differentiation strategy, the automobile industry had the same result. For the same reason, because this period is a time that selection mechanism is working, by which many firms are kicked out, firms should pursue a product differentiation strategy to become one of the few survivors. As an alternative explanation, economy of scale should be established to compete with other firms through price competition in order to survive in the industry by following firms that developed the dominant design so that firms that are not able to achieve economies of scale should pursue the differentiation strategy to survive.

Table 30. The comparison between survival analyses in mobile and automobile industry

	Automobile	Mobile	Automobile	Mobile	Automobile
	Pre-Shakeout Period		Shakeout Period		Post-Shakeout Period
Firm Size	**Positive**	**Positive**	Positive		Positive
Early Entry	Positive		Positive	Negative	Positive
Technology Level		Positive		Positive	
Technology Growth	**Positive**	**Positive**			
Product Diversity				Positive	
Product Difference	Negative		**Positive**	**Positive**	Negative

6.2 Implications

Although an adaptation strategy that increases survival probability of firms is different depending on industry and time, it is also true that there are some common results. The common adaptation strategies are that prior to a shakeout, a technology increase rate has a positive effect on survival of a firm, while product differentiation increases survival probability at the time of shakeout. Prior to a shakeout, it is a time to race with other firms not to be left behind. This period is one in which a technology increase rate is rapid as the number of firms increases. Therefore, firms that cannot keep pace with this fast increase rate will be kicked out of the industry.

In addition, a shakeout is a time when a big destructive wave is surging. At this period, most firms are kicked out. Therefore, to survive this period, firms should use an adaptation strategy to survive price competition and achieve economies of scale as they follow the dominant design, as proposed by previous studies, or increase survival possibility through product differentiation. Therefore, attempting product differentiation, which is different from what other firms do during the shakeout period (in which most firms are kicked out), would increase survival possibility, and this is a new adaptation strategy.

6.3 Contribution and limitation

This paper aims to reinterpret the industry development process from the evolutionary economics viewpoint. The two most significant differences between the neoclassical economics and evolutionary economics are whether difference of industry is considered and whether dynamics over time is considered. Although previous studies attempted interpretation of the industry development process in terms of evolutionary economics viewpoints, they did not reflect the differentiation of evolutionary economics sufficiently. In particular, few studies have been done to reflect both such differences and dynamics in empirical studies. However, this paper takes dynamics over time into consideration and reflects differences of industry by employing differentiated product-level data from previous studies.

In addition, this paper applied the discussion of selection and adaptation in evolutionary economics into the discussion of industry development for the first time and determined whether such discussion can provide an effective study framework. In this regard, a study framework of selection and adaptation was applied to automobile and mobile industries to conduct empirical analysis. As a result, we verified that our study framework, considering selection and adaptation in balance, can be a good alternative to explain the industry evolution process as well as verifying the dynamics of selection mechanism and adaptation strategy.

There are many reasons why previous studies did not consider adaptation concepts actively. For example, data acquisition was not easy due to the study characteristic in relation to industry evolution concerning more venerable industries, survey analysis is not applicable, and adaptation efforts of firms are difficult to be quantified despite use of financial data. In particular, an innovation strategy uses innovation variables such as R&D expense and the number of patents produced; however, these variables are limited to see a variety of aspects of innovation strategy. Due to such limitations, previous studies concentrated on characteristics of firms that are not changeable, such as a size of firm or entry timing, rather than adaptation efforts of firms. That is, the main discussion of previous studies was focused on selection rather than adaptation.

To overcome this limitation, this study attempted analysis using nearly all product data that was never employed before in related previous studies. Studies in the field of business administration have used a method of firm-level discussion by analyzing products released by firms several times. However, the focus of business administration is on firms, so those studies are regarded as case studies only. However, this study included all products that existed in each industry of interest; thus, this study can draw not only firm-level discussion but also industry-level discussion. Therefore, from the methodological point of views, this study is the first to apply the method to an entire industry and also is a differentiated study applied over a long-term analysis period. In addition, this study contributed to the interdisciplinary study of product analysis, which was only dealt with in business administration or engineering studies. For example, a strategy that increases size of firms and achieving economies of scale during the shakeout period, according to the identified implications from existing studies, and survives in subsequent price competition may not be an option for every firm. However, the strategy derived in this study is innovation and product strategies, which can be applicable and executable for all firms.

That is, this study contributed to application of a new analysis framework, as with selection and adaptation in evolutionary economics, to related studies from a theoretical viewpoint. It also contributed to connection into industry-level discussion utilizing product data from a methodological viewpoint. Through such a differentiated theoretical framework and methodology, an internal aspect of industry evolution, which could not have been disclosed up until now, was observed; thereby, strategic implications that are applicable to firms were presented in this study.

This study has a limitation of data acquisition since it analyzed old industries. For example, some firms with experiences in the bicycle or horse wagon industry entered into the automobile industry; however, this could not be reflected in this study due to data limitation.

In addition, since this study derived adaptation strategies through product analysis, this method cannot be applied to petrochemical or services industry in which the concept of product is ambiguous.

As a last limitation, this paper made an effort to derive generalized results as much as possible by intentionally selecting industries of considerably different characteristics. However, it is not certain yet that adaptation strategies derived in this study are also applicable to other industries. Few empirical studies have yet been conducted in consideration of adaptation strategies of firms. Therefore, it is expected that more generalized results will be derived through follow-up studies.

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Appendix

Table Appendix 31. The comparison of firm survival analysis by different reference year of pre-shakeout in automobile industry

	Pre-Shakeout (Base) ~ 1911	Pre-Shakeout (-2 years) ~ 1909	Pre-Shakeout (+2 years) ~ 1913
Firm Size Dummy	-40.081***	-35.065***	-35.032***
	(0.446)	(0.445)	(0.444)
First Mover Dummy	-0.894***	-0.891***	-0.868***
	(0.208)	(0.209)	(0.200)
Technology Level	0.295	0.198	0.072
	(0.795)	(0.841)	(0.829)
Technology Growth	-0.016*	-0.017**	-0.016*
	(0.008)	(0.009)	(0.008)
Product Dispersion	-0.076	-0.078	-0.090
	(0.072)	(0.074)	(0.071)
Product Difference	0.111*	0.099*	0.087
	(0.059)	(0.060)	(0.062)
Log Likelihood	-393.3	-393.8	-419.0
Observation	233	174	322

Notes: The values in parentheses are standard errors; *, ** and *** indicate statistical significance at the 10, 5 and 1% levels, respectively.

Table Appendix 32. The comparison of firm survival analysis by different reference year of shakeout in automobile industry

	Shakeout (Base) 1911 ~ 1927	Shakeout (-2 years) 1913 ~ 1925	Shakeout (+2 years) 1909 ~ 1929
Firm Size Dummy	-36.327***	-37.282***	-40.309***
	(0.411)	(0.416)	(0.414)
First Mover Dummy	-0.828***	-0.818***	-0.825***
	(0.264)	(0.265)	(0.262)
Technology Level	0.204	0.074	0.285
	(0.833)	(0.833)	(0.737)
Technology Growth	0.008	0.007	0.007
	(0.009)	(0.010)	(0.008)
Product Dispersion	0.043	0.035	0.054
	(0.061)	(0.061)	(0.053)
Product Difference	-1.098**	-0.959**	-1.175**
	(0.503)	(0.436)	(0.554)
Log Likelihood	-232.3	-200.9	-201.2
Observation	1458	1024	1534

Notes: The values in parentheses are standard errors; *, ** and *** indicate statistical significance at the 10, 5 and 1% levels, respectively.

Table Appendix 33. The comparison of firm survival analysis by different reference year of post-shakeout in automobile industry

	Post-Shakeout (Base) 1927 ~	Post-Shakeout (-2 years) 1925 ~	Post-Shakeout (+2 years) 1929 ~
Firm Size Dummy	-35.765***	-43.778***	-44.798***
	(0.491)	(0.517)	(0.543)
First Mover Dummy	-0.936*	-0.935*	-1.329**
	(0.539)	(0.538)	(0.652)
Technology Level	1.389	1.813	1.384
	(1.240)	(1.474)	(1.438)
Technology Growth	-0.017	-0.021	-0.016
	(0.021)	(0.023)	(0.024)
Product Dispersion	-0.102	-0.118	-0.228
	(0.114)	(0.147)	(0.352)
Product Difference	0.801**	0.762**	0.860*
	(0.383)	(0.381)	(0.476)
Log Likelihood	-83.48	-79.47	-50.60
Observation	418	476	325

Notes: The values in parentheses are standard errors; *, ** and *** indicate statistical significance at the 10, 5 and 1% levels, respectively.

Table Appendix 34. The comparison of firm survival analysis by different reference year of pre-shakeout in mobile industry

	Pre-Shakeout (Base) ~ 2003	Pre-Shakeout (-2 years) ~ 2001	Pre-Shakeout (+2 years) ~ 2005
De novo Dummy	-1.012	-1.007	-1.034
	(0.710)	(0.708)	(1.141)
Firm Size Dummy	-34.860***	-36.857***	-45.619
	(2.347)	(2.342)	(0.000)
First Mover Dummy	0.960	0.962	1.336
	(0.860)	(0.860)	(1.358)
Technology Level	-5.389**	-5.430**	-1.821*
	(2.682)	(2.704)	(0.991)
Technology Growth	-0.015*	-0.015*	-0.018**
	(0.008)	(0.008)	(0.009)
Product Dispersion	0.118	0.118	0.054
	(0.221)	(0.221)	(0.206)
Product Difference	0.946	0.946	-0.079
	(1.257)	(1.254)	(0.575)
Log Likelihood	-7.319	-7.322	-9.504
Observations	117	94	143

Notes: The values in parentheses are standard errors; *, ** and *** indicate statistical significance at the 10, 5 and 1% levels, respectively.

Table Appendix 35. The comparison of firm survival analysis by different reference year of shakeout in mobile industry

	Shakeout (Base) 2004 ~	Shakeout (-2 years) 2002 ~	Shakeout (+2 years) 2006 ~
De novo Dummy	0.161	-0.706	0.161
	(0.808)	(0.832)	(0.808)
Firm Size Dummy	0.295	1.649	0.295
	(0.933)	(1.146)	(0.933)
First Mover Dummy	2.050***	1.054*	2.050***
	(0.735)	(0.622)	(0.735)
Technology Level	-7.535**	-12.347***	-7.535**
	(3.771)	(4.578)	(3.771)
Technology Growth	-0.037	0.042	-0.037
	(0.055)	(0.035)	(0.055)
Product Dispersion	-1.100**	-2.471***	-1.100**
	(0.467)	(0.690)	(0.467)
Product Difference	-2.702*	-2.175***	-2.702*
	(1.419)	(0.773)	(1.419)
Log Likelihood	-18.05	-17.18	-18.05
Observations	242	287	214

Notes: The values in parentheses are standard errors; *, ** and *** indicate statistical significance at the 10, 5 and 1% levels, respectively.

Abstract (Korean)

산업이 생성된 이후에 많은 기업의 진입이 일어나지만, 이후 기업의 수가 급감하는 Shakeout 현상을 경험한다. 산업 생애 주기 이론에 따르면, 산업은 Shakeout 시기를 전후로 산업 전반에서 급격한 변화가 일어난다. 특히 산업구조의 변화의 경우, 심한 경우 완전 경쟁 시장에서 독과점에 이르기도 한다. 따라서 산업구조의 변화의 원인을 밝힐 수 있다는 점에서 Shakeout 은 연구할 가치가 있다.

한편 기업 측면에서, Shakeout 시기는 대규모 퇴출이 일어나기 때문에, 이 시기의 생존 전략은 매우 중요하다. 게다가 Shakeout 시기에 생존한 대부분의 기업들은 Shakeout 시기 이후의 산업 안정기 동안 장기간 시장에 머무르며, 주도적 지위를 유지할 수 있기 때문에 그 의의는 더 크다고 할 수 있다.

이러한 중요성으로 인하여, Shakeout 시기에서의 생존의 법칙을 밝히려는 연구는 많이 이루어졌다. 하지만 기업의 규모, 진입 시기, 진입 전 경험에 관한 연구가 주를 이루며, 이러한 생존 요인은 기업이 변경하기 어려운 요소들로 기업에게 많은 시사점을 제공하지 못하고 있다. 즉, 선행 연구에서 기업은 시장 환경에 의해 선택되는 수동적인 존재와 다름 없었다. 하지만, 진화 경제학의 선택과 적응의 개념에

따르면, 기업은 환경에 의해 선택되기도 하지만, 적응 노력을 통해 시장 환경에 적응할 수 있는 능동적 존재로 인식해야 한다. 따라서 본 논문에서는 기업의 적응 전략과 시장의 선택 메커니즘을 동시에 고려하여 기존 연구들에서 도출하지 못했던 시사점을 제시하는 것을 목적으로 한다. 그리고 Shakeout 시기와 Shakeout 전후는 산업의 특성에서 많은 이질성을 보인다. 따라서 선택의 메커니즘이 변할 수 있으며, 이 경우 적응 전략은 달라질 것이다. 따라서, 산업 진화의 단계를 구분하여, 적응 전략과 선택 메커니즘을 도출하고자 한다. 이를 위해 20 세기의 자동차 산업과 21 세기 모바일 산업을 통한 실증 분석을 실시하였다. 두 산업의 특성과 발생 시기는 매우 상이하며, 시기와 산업 특성에 따른 적응 전략과 선택 메커니즘의 차이 속에서 공통적인 원리에 가까운 결과를 도출하기 위해 의도적으로 선택하였다.

한편, 객관적인 적응 전략 변수의 도출에는 많은 장애 요인이 있기 때문에, 실증 분석이 거의 이루어지지 못한 것으로 보인다. 본 연구에서는 제품 수준의 데이터를 사용하여 이러한 장애 요인의 극복을 시도하였다.

사용된 데이터는 1905 년부터 1942 년까지의 총 21337 개의 미국의 자동차 데이터와 1994 년부터 2012 년까지의 총 5508 개의 모바일 제품 데이터이다. 이 제품 데이터로부터 도출된 적응 전략 변수는 기업의 기술 수준, 기업의 기술 증가율, 제품 다각화, 제품 차별화이다.

적응 전략 변수와 함께 선행 연구로부터 도출된 기업의 규모, 기업의 진입 시기, 기업의 산업 진입 전 경험 여부와 같은 주요 선택 요인을 분석에 포함시키고, 산업의 진화 단계에 따라 기업의 적응 전략과 선택 메커니즘이 어떻게 달라지는지를 시간 변수를 포함하는 콕스 비례 위험 모형을 사용하여 분석하였다.

위와 같은 방법으로 실시된 두 가지 실증의 주요 결과는 다음과 같다. 두 산업의 실증 분석 결과 도출된 공통된 적응 전략은 첫째, Shakeout 이전에는 기술 증가율이 생존에 긍정적이라는 점이다. Shakeout 이전 시기는 다른 기업에게 뒤쳐지지 않기 위해 레이스를 펼치는 과정이라 할 수 있다. 이 시기는 기업의 수가 증가함에 따라 기술의 증가 속도가 매우 빠른 시기이다. 따라서 이러한 빠른 증가 속도를 따라가지 못한 기업이 퇴출된다.

둘째, Shakeout 시기에는 제품 차별화를 시도해야 생존 확률을 높일 수 있다는 점이다. 그리고 Shakeout 시기는 대부분의 기업이 퇴출된다. 따라서 이 시기에 살아남기 위해서는 선행 연구들이 제시하는 바와 같이 Dominant Design 을 만들어 규모의 경제를 이루고, 이를 통해 가격 경쟁에서 살아남는 적응 전략을 사용하거나, 제품 차별화를 통해 생존 가능성을 높여야 함을 의미한다. 따라서 대부분이 퇴출되는 Shakeout 시기에서 오히려 다른 기업과 다르게 제품 차별화를 시도하는 전략은 지금까지 알려 지지 않은 새로운 적응 전략이라 할 수 있다.

본 논문은 여러 부분에서 선행 연구와의 차별성과 의의는 다음과 같다. 우선 진화 경제학의 선택과 적응 개념에서 두 개념을 동시에 고려하였으며, 이를 통해 기업을 환경에 의해 선택되는 수동적 존재가 아닌 적응을 통해 생존하는 능동적 존재로 인식할 수 있었다. 이러한 시도를 통해 Shakeout 시기에 있어서 실천 가능한 시사점을 제공할 수 있다는 점에서 의의가 있다.

그리고 제품 수준의 데이터를 사용하여 적응 전략을 도출하여 기업의 이질성을 고려할 수 있었다. 그리고 경영학이나 제품 동학에서 주로 다루어 오던 제품 분석을 통해 산업의 진화와 연결시키고 있다는 점에서 의의가 있다. 왜냐하면 제품 수준의 데이터는 주로 경영학이나 공학에서 주로 다루어 왔기 때문이다. 따라서 본 연구는 경영학과 경제학을 연결하는 학제간 연구로서의 의의를 가진다.

마지막으로, 기업의 적응 노력을 포함하여 산업의 진화 과정을 모형화하려는 시도는 여러 차례 있었지만, 이를 실증한 경우는 거의 없었다. Gort and Klepper (1982) 역시 모형을 제시하였지만, 결국 우회적인 방법으로 실증하였으며, 적응 전략을 포함시킨 직접적 실증에는 실패하였다. 즉, 진화 경제학의 틀에서 적응 노력을 적극적으로 고려한 매우 드문 연구로써 가치가 있으며, 제품 데이터를 통한 적응 전략 도출 방식 역시 미래의 실증 연구 방향을 제시한다는 점에서 의의가 있다.

주요어 : 셰이크아웃, 산업생애주기 이론, 제품 분석, 진화 경제학, 선택과 적응, 생존 분석

학번 : 2006-21090